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Contract Structure, Risk Sharing, and Investment Choice

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Abstract

Few microfinance-funded businesses grow beyond subsistence entrepreneurship. This paper considers one possible explanation: that the structure of existing microfinance contracts may discourage risky but high-expected return investments. To explore this possibility, I develop a theory that unifies models of investment choice, informal insurance, and formal financial contracts. I then test the predictions of this theory using a series of experiments with clients of a large microfinance institution in India. The experiments confirm the theoretical predictions that joint liability creates two inefficiencies. First, borrowers free-ride on their partners, making risky investments without compensating partners for this risk. Second, the addition of peer-monitoring overcompensates, leading to sharp reductions in risk-taking and profitability. However, the theoretical prediction that group lending will crowd out informal insurance is not borne out by experimental evidence. While observed levels of informal insurance fall well short of the constrained Pareto frontier under both individual and joint liability, joint liability increases observed insurance transfers. Equity-like financing, in which partners share both the benefits and risks of more profitable projects, overcomes both of these inefficiencies and merits further testing in the field.

1 Introduction

In 2005, designated the "International Year of Microcredit" by the United Nations, microfinance institutions around the world issued approximately 110 million loans with an average size of $340. The following year, Muhammad Yunus and Grameen Bank received the Nobel Peace Prize for their efforts to eliminate poverty through microcredit. But while the provision of small, uncollateralized loans to poor borrowers in poor countries may help alleviate poverty, there is little evidence that microfinance-funded businesses grow beyond subsistence entrepreneurship. Few hire employees outside their immediate families, formalize, or generate sustained capital growth.

This paper considers one possible explanation for this phenomenon: the structure of existing microfinance contracts *themselves* may discourage risky but high-expected return investments. Typical microfinance contracts produce a tension between mechanisms that tend to reduce risk-taking, such as peer monitoring, and those that tend to encourage risk-taking, such as risk-pooling. Much of the theoretical literature has focused on joint liability, a common feature in most microfinance programs, as a means to induce peer monitoring and mitigate *ex ante* moral hazard over investment choice (e.g., Stiglitz 1990, Varian 1990). Under joint liability, small groups of borrowers are responsible for one another's loans. If one member fails to repay, all members suffer the default consequences. While this mechanism has been widely credited with making it possible, indeed profitable, to lend to poor borrowers in poor countries, there have long been suspicions that peer monitoring may overcompensate and produce too little risk relative to the social optimum (Banerjee, Besley, and Guinnane 1994). At the same time, joint liability encourages risk pooling—not only does the threat of common default induce income transfers to members suffering negative shocks, but the repeated interactions of microfinance borrowers are a natural environment for the emergence of informal insurance. Both of these risk pooling factors may increase borrowers' willingness to take risk.

To shed light on how microfinance contracts affect investment choices, this paper develops a theory that unifies models of investment choice, informal insurance with limited commitment, and formal financial contracts. It then implements a corresponding experiment with actual microfinance clients in India, with the ultimate aim of understanding how microfinance can most effectively stimulate entrepreneurship, encourage growth, and reduce poverty.

The theory builds on a simple model of informal risk-sharing in the spirit of Coate and Ravallion (1993) and Ligon, Thomas, and Worrall (2002). In this model, two risk-averse individuals receive a series of income draws subject to idiosyncratic shocks. In the absence of formal insurance and savings, they enter into an informal risk-sharing arrangement that is sustained by the expectation of future reciprocity. I enrich this model by endogenizing the income process, allowing agents to optimize their investment choices in response to the insurance environment. Contrary to much of the static investment choice literature in microfinance, in this model risky projects generate higher expected returns than safe projects, reflecting the natural assumption that individuals must be compensated for additional risk with additional returns.[1] On this framework I then overlay formal financial contracts. I consider in turn individual liability, joint liability, and an equity-like contract in which all investment returns are shared equally.

The theoretical analysis produces two key results. First, it demonstrates that joint liability contracts may crowd out informal insurance. By effectively mandating income transfers to assist loan repayment, joint liability eases the sting of reversion to autarky and makes cooperation harder to sustain. Second, informal insurance tends to increase risk taking. Contrary to standard risk-sharing models, this has the surprising implication that we may find *more* informal insurance among risk-tolerant individuals whose willingness to take riskier

[1]Following Stiglitz (1990), most theoretical work in microfinance has assumed that riskier investments represent at best a mean-preserving spread of the safer choice and often generated a lower expected return. Examples include Morduch (1999), Ghatak and Guinnane (1999), and Armendáriz de Aghion and Gollier (2000).

investments expands their scope for cooperation.

The model also illustrates two opposing influences of joint liability on investment choice. Mandatory transfers from one's partner encourage greater risk taking by partially insuring against default. Risk-taking borrowers may compensate their partners for this insurance with increased transfers when risky projects succeed, or they may "free-ride," forcing their partners to insure against default without compensating transfers. The parallel need to *provide* this insurance counters the risk-encouragement effect of receiving it, and relatively risk-averse individuals may elect safer investments to avoid joint default should their partners' projects fail.

While these models offer useful insights, in the context of repeated interactions they produce a multiplicity of equilibria, and theory alone can provide only partial guidance regarding the likely consequences of informal insurance and formal contracts for investment behavior. To shed further light on these questions, I conducted a series of experiments with actual microfinance clients in India. The experiments capture key elements of the theoretical models and the microfinance investment decisions they represent. Based on extensive piloting, I designed the games to be easily understood by typical microfinance clients—project choices and payoffs were presented visually, all randomizing devices used common items and familiar mechanisms (e.g., guessing which of an experimenter's hands held a colored stone), and game money was physical—and confirmed understanding at numerous points throughout the experiment. Individuals were matched in pairs, which dissolved at the end of each round with a 25% probability in order to simulate a discrete-time, infinite-horizon model with discounting. In each round, subjects could use the proceeds of a "loan" to invest in one of several projects that varied according to risk and expected returns. Returns were determined through a simple randomizing device, after which individuals could engage in informal risk-sharing by transferring income to their partners. In order to play in future rounds, subjects needed to repay their loans according to the terms of a formal financial contract, which I varied across treatments.

I considered five contracts: autarky, individual liability, joint liability, joint liability with a project approval requirement, and an equity-like contract in which all income was shared equally. Much of the microfinance literature assumes a local information advantage; therefore, to test the role of information, I conducted each of the treatments under both full information, where all actions and outcomes were observable, and limited information, where individuals observed only whether their partner earned sufficient income to repay her loan. At the end of the experiment, one period was randomly selected for cash payment.[2]

A laboratory-like experiment allows precise manipulation of contracts, information, and investment returns to a degree that would be impractical for a natural field experiment. Moreover, even in carefully constructed field experiments, low periodicity, long lags to outcome realization, fungibility of investment funds and measurement issues associated with micro-business data complicate the use of investment choice as an outcome variable.[3] An experiment overcomes each of these challenges. While the use of an experiment entails a tradeoff between control and realism, I attempted to maximize external validity with meaningful payoffs of up to one week's reported income, subjects drawn from actual microfinance clients, and an experimental design that closely simulates the underlying theory.

This experiment generated several interesting results. First, actual informal insurance fell well short of not only the full risk-sharing benchmark but also the constrained optimal insurance arrangement. Average net transfers were only 14% of the full risk-sharing amount and approximately 30% of transfers in the constrained optimal arrangement. This shortfall may explain why we see semi-formal risk-sharing mechanisms, such as the state-contingent loans used for risk smoothing in northern Nigeria (Udry 1994), and casts doubt on constrained

[2] As described in Charness and Genicot (2007), this payment structure prevents individuals from self-insuring income risk across rounds. The utility maximization problem of the experiment matches that of the theoretical model.

[3] Giné and Karlan (2007), for example, were able to randomize across joint and individual loan contracts with a partner bank in the Philippines. They find no difference in default rates and faster expansion of the client base under individual liability but are unable to evaluate investment behavior.

Pareto optimality as the focal selection criteria for informal risk-sharing equilibria.

Second, joint liability induced greater *upside* risk-sharing than individual liability. That joint liability caused borrowers to assist their partners' loan repayments is not surprising; however, transfers as a percentage of the full risk-sharing amount *excluding transfers required for loan repayment* nearly doubled under joint liability. While theory predicts such a response for relatively risk-tolerant individuals making high-risk investments, the effect was broadly distributed and suggests a behavioral response.[4]

Third, despite these increased transfers, joint liability produced free-riding. Risk-tolerant individuals, as measured in a benchmarking risk experiment, took significantly greater risk under joint liability with limited information. Yet the transfers they made when successful did not increase with the riskiness of their investments or the expected default burden they placed on their partners. Increased risk-taking was not evident under joint liability with complete information, and when individuals were given explicit approval rights over their partners' investment choices, risk-taking fell below the autarky level. Together, these results indicate that increased risk-taking was not the product of cooperative insurance. They also suggest that peer monitoring mechanisms, as embodied in explicit project approval rights, not only prevent *ex ante* moral hazard but more generally discourage risky investments, irrespective of whether or not such risks are efficient.

Fourth, the equity-like contract increased risk-taking and expected returns relative to other contracts while at the same time producing the lowest default rates. Increased risk was almost always hedged across borrowers, with the worst possible joint outcome still sufficient for loan repayment. These results are encouraging and suggest that equity-like contracts merit further exploration in the field.

[4] The economics literature has largely focused on importance of social capital in supporting lending arrangements. See, for instance, Karlan (2007), Abbink, Irlenbusch, and Renner (2006), and Cassar, Crowley, and Wydick (2007). Two notable exceptions are Ahlin and Townsend's (2007) work in Thailand and Wydick's (1999) in Guatemala, both of which find that social ties can *lower* repayment rates. However, sociological and anthropological case studies explore the possibility that microfinance and group lending in particular may affect social cohesion (e.g., Lont and Hospes 2004, Fernando 2006, Montgomery 1996).

It is worth emphasizing that both the theory and experiment abstract from effort, willful default, partner selection, and savings. This is not meant to imply that any of these factors is unimportant.[5] Instead, my purpose is to isolate the elements of risk-sharing, investment choice, and formal contracts and to explore their implications.

The rest of this paper is organized as follows. Section 2 places this paper in the context of related literature. Section 3 develops the model of informal risk-sharing with formal financial contracts and endogenous investment choice. Proofs are contained in Appendix B, unless otherwise noted. Section 4 describes the experimental design, and Section 5 presents the experimental results. Section 6 concludes.

2 Related Literature

This paper builds on a theoretical literature that characterizes optimal self-enforcing risk-sharing arrangements in a variety of settings. Among others in this vein are Coate and Ravallion (1993), Ligon, Thomas, and Worrall (2002), Kocherlakota (1996), and Genicot and Ray (2003). An extensive empirical literature documents the importance of informal insurance arrangements as a risk management tool for those who lack access to formal insurance markets (e.g., Townsend 1994, Udry 1994, Fafchamps and Lund 2003, Fernando 2006, Foster and Rosenzweig 2001). Taken as a whole, the empirical evidence suggests that informal risk coping strategies do not achieve full risk pooling even though in some cases they perform remarkably well. This paper adds to an emerging experimental literature (Charness and Genicot 2007, Barr and Genicot 2007, Robinson 2007) that uses the precise control

[5] The theory of strategic default on microfinance contracts is explored in Besley and Coate (1995) and Armendáriz de Aghion (1999), while Armendáriz de Aghion and Morduch (2005) and Laffont and Rey (2003) both treat moral hazard over effort in detail. To the best of my knowledge, neither area has seen careful empirical work in the context of microfinance. Similarly, the empirical implications of savings for informal risk sharing arrangements remain poorly understood. Bulow and Rogoff's (1989) model of sovereign debt implies that certain savings technologies can unravel relational contracts, including informal insurance. Ligon, Thomas, and Worrall (2000) consider a simple storage technology and find that the ability to self-insure can crowd out informal transfers, with ambiguous welfare implications.

possible in an experimental setting to understand how such mechanisms work in practice.

This paper also contributes to literature on peer monitoring and other elements of typical microfinance contracts. Since Stiglitz (1990), most of this literature has adopted the convention that riskier investments at best match the expected return of safer choices. Thus, great attention has been paid to mechanisms capable of reducing *ex ante* moral hazard over investment choice (Armendáriz de Aghion and Morduch 2005, Varian 1990, Conning 2005). In contrast, this paper considers investments where additional risk is compensated with increased expected returns, a natural assumption that has received little attention to date. In this setting, peer monitoring can discourage efficient risk-taking, a result which complements Banerjee, Besley, and Guinnane's (1994) prediction of excessive and socially inefficient monitoring in credit cooperatives.

This research also fits into the growing literature on the relative merits of group versus individual liability lending. When all decisions are taken cooperatively (Ghatak and Guinnane 1999) or when binding *ex ante* side contracts are feasible (Rai and Sjöström 2004) these mechanisms are identical; however, joint liability lending is most prevalent in settings where binding, complete contracts are not feasible. Madajewicz (2003, 2004) compares individual and group lending directly, focusing on monitoring costs and the relationship between available loan size and borrower wealth, but this basic comparison remains difficult to answer empirically. In practice, variation in loan types is likely the product of selection on unobserved characteristics by either the borrower or the lender. Giné and Karlan (2007) overcome this limitation with a large, natural field experiment that randomized individuals into joint and individual liability loan contracts. They find no impact of joint liability on repayment rates and some evidence that individual liability centers generated fewer dropouts and more new clients.

Because precise contract variation, control, and measurement are all limited in such "real-life" experiments, laboratory experiments constitute a valuable alternative. Abbink, Irlenbusch, and Renner (2006) study the effect of group size and social ties on loan repayment rates in an experimental setting, which allowed controlled variation that would have been impractical in a natural setting. Giné, Jakiela, Karlan, and Morduch (2007) pioneered the use of laboratory experiments to unpack the effects of various design features in microfinance contracts using a relevant subject pool. My paper explores in more detail a number of the issues they illuminated, with a number of key differences. Most importantly, I allow for informal insurance, an important risk management device for poor borrowers in poor countries, which may mitigate free-riding by enabling risk-taking individuals to compensate their partners for default insurance. My experiments also highlight the role of information by varying the information environment in all treatments and present subjects with an optimization problem equivalent to a discrete-time, infinite-horizon model. This allows for comparison between the experimental results and the underlying theory described in Section 3. Finally, I explore the effects of equity, a potential microfinance contract that may encourage investments with higher expected returns.

3 A Model of Investment Choice and Risk Sharing

3.1 Description of the Economic Environment

Consider a world where two individuals make periodic investments that are funded by their endowments and possibly outside financing. Each period, they each allocate their investment between a safe project that generates a small positive return with certainty or a risky investment that may fail but compensates for this risk by offering a higher expected return.

Individuals are risk averse, but they cannot save and lack access to formal insurance. In order to maximize utility they therefore enter into an informal risk-sharing arrangement. If one of them earns more than the other, she may give something to her less fortunate partner. In this model, she does this not out of the goodness of her heart, but in expectation of reciprocity. In the future, she may be the one who needs help. Such transfers must therefore be self-enforcing: an individual will transfer no more than the discounted value of what she expects to get out of the relationship in the future.

Terms of the outside financing are set by a third party. They specify repayment requirements and default penalties, typically the denial of all future credit, and may include income transfer rules ranging from joint liability to equity. The following subsection describes the model setup and timing.[6]

3.2 Model Setup and Timing

I model this setting using a discrete-time, infinite-horizon economy with two identical agents indexed by $i \in \{A, B\}$ and preferences

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t u(c_t^i)$$

at time $t = 0$, where $\mathbb{E}_0$ is the expectation at time $t = 0$, $\beta \in (0, 1)$ is the discount factor, $c_t^i \geq 0$ denotes the consumption of agent i at time t, and u represents agents' per-period von Neumann-Morgenstern utility function, which is assumed to be nicely behaved: $u'(c) > 0, u''(c) < 0 \quad \forall c > 0$ and $\lim_{c \to 0} u'(c) = \infty$. Where not required for clarity, I suppress the time subscript in the notation that follows.

Individual are matched under a formal financial contract Γ_G that specifies the feasible range of transfers between parties, loan repayment terms, and the availability of future financing based on current outcomes. The following subsection describes these contracts in more detail. Then each stage of the game proceeds as follows:

1. Each individual has access to an endowment, I, and a loan $D_t^i \in \{0, D\}$ where $D_0^i = D$

[6]Note that the model as described, in particular the structure of formal contracts, is more general than required for the discussion herein. I include it for consistency with ongoing work-in-progress that explores contract structures, information, and preference asymmetry in more detail.

and future borrowing is determined by the terms of the formal lending contract. From her total capital, $I + D_t^i$, she allocates a share $\alpha_t^i \in [0, 1]$ to a risky investment that with probability π returns R for each unit allocated and 0 otherwise. The remainder, $1 - \alpha_t^i$, she allocates to a safe investment that returns $S \in [1, R\pi)$ with certainty.

(a) When the risky project succeeds, individual i's total income is $y_h^i(\alpha^i, D^i) = \{\alpha^i R + (1 - \alpha^i)S\}(I + D)$.

(b) When the risky project fails, her income is $y_l^i(\alpha^i, D^i) = \{(1 - \alpha^i)S\}(I + D^i)$.[7]

2. The state of nature is realized and each individual receives her income, y^i. Denote by $\theta \in \Theta = \{(j, k); j, k \in (l, h)\}$ the state of nature, such that for any state θ, $(y^A, y^B) = (y_j^A, y_k^B)$. For notational simplicity I write the four states of nature as hh, hl, lh, ll.

3. Because individuals are risk averse, they have an incentive to share risk and enter into an informal risk-sharing contract that may extend beyond any formal sharing rules.

(a) This informal contract is not legally enforceable and thus must be self-sustaining. I assume that if either party reneges upon the contract, both individuals henceforth transfer only what is required by the formal contract ($\tau^i = \underline{\tau}^i$).

(b) Each individual chooses to transfers an amount $\tau^i \in [\underline{\tau}^i, y^i]$ to her partner. Her income after transfers is $\tilde{y}^i = y^i - (\tau^i - \tau^{-i})$.

(c) The financial contract, Γ_G^1, specifies the feasible range of transfers each individual can make. Formally, $\Gamma_G^1 : (y^1, y^2) \to [\underline{\tau}^1, y^1] \times [\underline{\tau}^2, y^2]$.

4. The financial contract specifies the loan repayment (P_t^i) and the amount available in the next period (D_{t+1}^1). Formally, $\Gamma_G^2 : (\tilde{y}_t^1, \tilde{y}_t^2, D_t^1, D_t^2) \to (P_t^1, P_t^2, D_{t+1}^1, D_{t+1}^2)$.

[7] We could generalize the income process such that $y_t^i = y(\alpha, \theta)(1 + D_t^i)$, where $\theta \in \mathbb{R}^2$ is the state of nature and $y : [0, 1] \times \mathbb{R}^2 \to \mathbb{R}_+$. Define $\bar{y}(\alpha) = \int_\theta y(\alpha, \theta) f(\theta) d\theta$ and $\delta(\alpha) = \lim_{z \to 1^-} \int_{-\infty}^{y^{-1}(\alpha,z)} f(\theta) d\theta$, i.e., the probability that $y(\alpha, \theta) < 1$. The returns assumptions translate to $\partial\bar{y}(\alpha)/\partial\alpha > 0$—expected returns are increasing in risk—and $\partial\delta(\alpha)/\partial\alpha > 0$—the probability of a loss is also increasing in α. This form allows for correlated returns through the distribution of θ and can eliminate the discontinuity created by the default threshold in the simplified, specific model.

(a) Loan repayment (P_t^i) is determined mechanically. There is no willful default so if an individual has sufficient funds to repay her loan, she will. $P_t^i = \min(D_t^i, \tilde{y}_t^i)$.

(b) The loan amount available in the following period evolves according to the following laws of motion for each formal contract (described immediately below):

$$\Gamma_I \quad : \quad D_{t+1}^i = \begin{cases} D \text{ if } P_t^i = D_t^i = D \\ 0 \text{ otherwise} \end{cases}$$

$$\Gamma_J, \Gamma_E \quad : \quad D_{t+1}^i = \begin{cases} D \text{ if } P_t^i = D_t^i = D \ \forall i \\ 0 \text{ otherwise.} \end{cases}$$

5. Because agents cannot save, the specified loan repayment uniquely determines consumption for the period: $c_t^i = y_t^i - (\tau_t^i - \tau_t^{-i}) - P_t^i$.

3.3 Formal Contracts

I consider three types of contracts: individual liability (Γ_I), joint liability (Γ_J) and quasi-equity (Γ_E), which is equivalent to joint liability with third-party enforced equal sharing of all income. The first two contracts capture key elements of micro-lending contracts that exist in practice. The third is counterfactual and provides a benchmark formal risk-sharing arrangement, with practical implications discussed more fully in Section 5.

For each contract I normalize the interest rate on loans to zero and constrain the amount of financing to $D^i \in \{0, D\}$. I also exclude the possibility of willful default or *ex post* moral hazard—an individual will always repay if she has sufficient funds—in order to focus on investment choice and risk-sharing behavior. The formal contracts have the following features.

Individual liability. Under individual liability, Γ_I, there are no mandatory transfers, $\underline{\tau}^i = 0$, and an individual can borrow in the subsequent period if she repays her own loan in the current one, $D^i_{t+1} = D$ if and only if $P^i_t = D^i_t = D$.

Joint liability. Under joint liability, Γ_J, if either individual has insufficient funds to repay her loan, her partner must help if she can: $\underline{\tau}^i = \max(\min(y^i - D^i, D^{-i} - y^{-i}), 0)$.[8] An individual can only borrow in the subsequent period if both she and her partner repaid their loans in the current period: $D^i_{t+1} = D$ if and only if $P^i_t = D^i_t = D$ for $i \in \{A, B\}$.

Equity. Under the equity contract, Γ_E, individuals share their income equally such that $\underline{\tau}^i = \frac{1}{2}y^i$. As with joint liability, an individual can only borrow in the subsequent period if both she and her partner repaid their loans in the current period: $D^i_{t+1} = D$ if and only if $P^i_t = D^i_t = D$ for $i \in \{A, B\}$.

3.4 Characterization of Informal Insurance Arrangements and Investment Choice

An informal insurance arrangement specifies the net transfer from A to B for any state of nature θ given individuals' allocations to the risky asset (α^A, α^B). Since individuals are risk averse and $\pi R > S$, in autarky, both individuals will allocate an amount $\alpha^i \in (0, 1)$ to the risky asset. Because $\alpha^i > 0$, there exist at least two states of the world where the autarkic ratios of marginal utilities differ, and individuals will have an incentive to share risk. I assume individuals can enter into an informal risk-sharing contract supported by trigger strategy punishment. If either party reneges on the insurance arrangement, both members exit the informal insurance arrangement in perpetuity. Note that they are still subject to the transfer requirements, if any, of the formal financial contract. I will focus on the set of subgame perfect equilibria to this infinitely repeated game and restrict my attention to the constrained Pareto optimal arrangement. An equilibrium specifies a transfer arrangement $T(\alpha^A, \alpha^B) = (\tau_{hh}, \tau_{hl}, \tau_{lh}, \tau_{ll})$ for all investment choice pairs $(\alpha^A, \alpha^B) \in [0, 1]^2$ and an optimal

[8] I assume that this transfer requirement is mandatory. Alternatively, one could endogenize the transfer choice such that an individual would only make transfers required for debt repayment if the amount of the required transfer was less than her default penalty. In practice, borrowers almost always make such transfers and modeling the choice formally seems an unnecessary complication.

investment allocation $(\alpha^{*A}, \alpha^{*B})$ conditional on this set of transfer arrangements.

Conditional on individuals' allocations to the risky asset, the vector $T = (\tau_{hh}, \tau_{hl}, \tau_{lh}, \tau_{ll})$ fully specifies the transfer arrangement. Incentive compatibility requires that in any state of the world the discounted future value of remaining in the insurance arrangement must be at least as large as the potential one-shot gain from deviation.

In the absence of any mandatory transfers, define individual A's expected autarkic utility as

$$\bar{V}^A = \pi u(y^A_{h\cdot}) + (1-\pi)u(y^A_{l\cdot}).$$

Under the transfer arrangement T, her expected per-period utility is

$$V^A(T) = \pi^2 u(y^A_{h\cdot} - \tau_{hh}) + \pi(1-\pi)u(y^A_{h\cdot} - \tau_{hl}) + \pi(1-\pi)u(y^A_{l\cdot} - \tau_{lh}) + (1-\pi)^2 u(y^A_{l\cdot} - \tau_{ll}).$$

Incentive compatibility requires

$$u(y^A_\theta - \tau^A_\theta) - u(y^A_\theta) + \frac{V^A(T) - \bar{V}^A}{r} \geq 0, \ \forall\theta,$$

where $r = (1-\beta)/\beta$. When formal contracts specify a minimum transfer $\underline{\tau}_\theta$ in state θ, we modify the constraint accordingly:

$$u(y^A_\theta - \tau^A_\theta) - u(y^A_\theta - \underline{\tau}_\theta) + \frac{V^A(T) - V^A(\underline{T})}{r} \geq 0, \ \forall\theta$$

where $\underline{T} = (\underline{\tau}_{hh}, \underline{\tau}_{hl}, \underline{\tau}_{lh}, \underline{\tau}_{ll})$.

Conditional on the set of insurance arrangements, each individual selects

$$\alpha^{i*} = \arg\max_{\alpha^i} V^i(T(\alpha^i, \alpha^{-i})).$$ [9]

An equilibrium is a fixed point of this problem.

I now show that moving from autarky to an environment with incentive compatible informal insurance arrangements increases each individual's allocation to the risky asset.

Proposition 1 (informal insurance increases risk taking) *Let T be a non-zero, incentive compatible informal insurance arrangement with no mandatory minimum transfers and a Pareto weight equal to the ratio of individuals' marginal utilities in autarky. Then $\alpha^{i*}(T) > \alpha^{i*}(0)$.*[10]

Note that in contrast to informal insurance and consistent with standard portfolio theory (e.g., Gollier 2004), when insurance is *required* by joint liability, an individual's risk taking may decrease relative to autarky. Consider the following numerical example. Two individuals with CRRA utility and risk aversion parameter $\rho = 0.5$ are in an environment with $S = 1$, $R = 3$, $D = 1$, $\beta = 0.9$, and $\pi = 0.5$. In autarky, each individual's optimal allocation to the risky asset, α^*, is 0.25. Now consider the situation in which they are paired under joint liability and no informal insurance. There are now three Nash equilibria to the stage game: $(0, 1)$, $(1, 0)$ and $(0.25, 0.25)$. The first two equilibria demonstrate the risk mitigation effect of joint liability. In response to increased risk taking by their partners, individuals may reduce their own allocation to the risky asset relative to autarky.

Next I show that as an individual's allocation to the risky project increases, she is willing to sustain larger informal transfers

Proposition 2 (risk taking encourages insurance) *For any $\alpha' > \alpha$, the maximum sustainable transfer $\tau_\theta(\alpha', \cdot) \geq \tau_\theta(\alpha, \cdot)$ in any state θ where transfers are made.*

Taken together Propositions 1 and 2 imply a positive feedback between risk-taking and insurance. Improved insurance increases risk taking, which in turn makes it easier to support greater insurance.

[10] Note that this proposition requires convex production technology. With production non-convexities such as increasing returns to the risky investment, greater cooperation may lead to specialization wherein one party reduces her risk-taking in order to provide insurance so that her partner can take advantage of increasing returns.

In contrast to standard models of informal insurance with exogenous income processes, a model with endogenous investment choice has the interesting feature that more risk-tolerant individual *may* engage in greater risk sharing. Consider the following environment: $S = 1$, $R = 3$, $D = 1$, $\beta = 0.75$, and $\pi = 0.5$. The maximum sustainable insurance transfer is realized for individuals with $\rho = 0.55$ who select $\alpha^* = 0.42$. They transfer, 0.82 or 65% of the full risk-sharing amount in states lh and hl. More risk-tolerant individuals are too impatient to support additional transfers, while more risk averse individuals allocate a lower share to the risky asset. In the experimental setting described in Section 4, the optimal investment choice for two individuals with $\rho = 0.4$ generates a payoff (y_h, y_l) of $(160, 40)$ and supports a maximum transfer of 42, or 70% of the full insurance transfer. For two, more risk averse individuals with $\rho = 0.6$, the optimal investment choice generates a payoff of $(140, 50)$ and supports a maximum transfer of 26 or 59% of full insurance.

Proposition 3 (Mandatory Insurance and Informal Transfers) *Mandatory insurance reduces maximum sustainable informal transfers in states of nature when transfers are not required:* $\tau^*_{ij}(\underline{T} > 0) \leq \tau^*_{ij}(\underline{T} = 0)$ *if* $\underline{\tau}_{ij} = 0$. *In states where transfers are required* ($\underline{\tau}_{ij} > 0$)*, total transfers increase if and only if either* $\tau^*_{ij}(\underline{T} = 0) < \underline{\tau}$ *(i.e., the mandatory transfer rule is binding) or* $\frac{u'(y_j + \underline{\tau}_{ij})}{u'(y_i - \underline{\tau}_{ij})} < \frac{r + \pi_{ij}}{\pi_{ij}}$.

Figure 2 illustrates three effects of joint liability on static project choice: free-riding, risk mitigation, and debt distortion. The figure plots individual B's best response function for α^B with respect to α^A in the environment $S = 1$, $R = 3$, $D = 1$, $\beta = 0.75$, and $\pi = 0.5$ where $\rho^B = 0.4$. The dashed line shows $\alpha^{*B}(\alpha^A)$ under individual liability with no informal insurance. Because there is no strategic interaction in this setting, B's best response is constant. Under joint liability with no informal insurance, three distinct effects are evident. First, for low values of α^A, B takes greater risk, "free-riding" on the effective default insurance provided by A. As α^A rises, α^B returns to its level under individual liability; however, once $\alpha^A > 0.5$, B must make transfers to A to prevent default when A's project is unsuccessful. As a consequence, B reduces her own risk taking. Once A's risk taking is sufficiently large (here, $\alpha^A \approx 0.9$) the cost of providing default insurance is too great (B's payoff after transfers is states hl and, particularly, ll, is too low), the usual distortionary effects of debt with limited liability take over, and B's best response is to allocate all of her capital to the risky asset.

While information likely plays an important role in determining informal insurance arrangements and the interactions of microfinance borrowers, it is beyond the scope of this model. The preceding theory is all developed under the assumption of perfect information.[11] In order to shed some light on the role of information and as Section 4 discusses in detail, I conducted each of the experimental treatments under both full and limited information. In the limited information treatment, individuals observed only whether their partners earned sufficient income to repay their loans. All other information about actions and outcomes was voluntary and unverifiable. While not explicitly modeled, limited information likely reduces cooperation. See, for example, Chassang (2006), Green and Porter (1984), and Fudenberg and Maskin (1986) for discussions of how imperfect information can reduce cooperation and push equilibria away from the full-information Pareto frontier. Full information, on the other hand, increases the likelihood of unmodeled social elements such as privately costly, out-of-game punishments.

3.5 Summary of Theoretical Predictions

The following subsection summarizes the key theoretical predictions.

1. Relative to autarky, informal insurance will increase risk taking by risk-averse individuals.

2. Joint liability (mandatory insurance when one party has a low outcome) has four types

[11] The model under limited information is complex and deserves to be the subject of a separate paper. In ongoing work-in-progress, I explore the role of information and preference asymmetry in more detail.

of effects, the net impact of which is ambiguous.

(a) Static Project Choice: The existence of mandatory transfers directly affects project choice. This effect can be divided into two components:

   i. Free Riding: Mandatory transfers from one's partner encourage greater risk taking by partially insuring against default. In many situations, this will lead to "free-riding" where a borrower selects a risky project, saddles her partner with the need to insure against default, and does not compensate her for this insurance by transferring income when the risky project succeeds.

   ii. Risk Mitigation: Joint liability and mandatory transfers to one's partner may decrease risk taking as borrowers adjust their project choices to avoid joint default should their partners' projects fail.

   If the risk of default (or the cost of avoiding it) is sufficiently large, the standard distortion of debt with limited liability dominates and pushes individuals towards the riskiest choice.

(b) Informal Insurance: Joint liability changes the threat point of informal insurance in two ways:

   i. Crowding Out: Mandatory insurance reduces the cost of reversion to autarky and thus makes cooperation harder to sustain. This reduces informal insurance and in turn should decrease risk taking.

   ii. Limited Deviation Gain: In states where joint liability causes one party to assist the other's loan repayment, mandatory insurance reduces the potential momentary gain from defection—one cannot avoid making the required transfer. This will strengthen informal insurance and increase risk taking.

   When both parties have sufficient income to repay their loans, only the crowding out effect is present and formal insurance weakens informal insurance. When borrowers are relatively risk tolerant and the maximum gains to defection are relatively small, joint liability may increase informal insurance in those states where one party is unable to repay her loan without assistance.

(c) Dynamic Project Choice: A borrower who is responsible for the loan repayment of another and insufficiently compensated for this insurance may discourage risk taking dynamically through subgame perfect punishment strategies. In response to defection, one could terminate informal insurance or switch to a risky investment that inflicts on the defector either default risk or the need to insure against it. In equilibrium, this effect should reduce risk taking, though its magnitude is likely small.

(d) Explicit Approval Rights: Joint liability contracts may confer explicit approval rights over a borrower's partners' projects. These approval rights may be exogenous and absolute (Stiglitz 1990) or enforceable through social sanctions. Explicit approval rights exert two influences:

   i. Forced Project Punishment: Approval rights provide an additional punishment mechanism—those who don't cooperate can be forced into suboptimal projects. This encourages informal insurance and increases risk taking.

   ii. *Ex Ante* Project Veto: Approval rights can directly curtail excessive risk taking *ex ante* as partners simply veto or threaten to veto projects they deem "too risky."

When the risk of default is low even in the absence of approval rights or when borrowers are likely to cooperate on investment choice, we expect the forced project punishment effect to dominate. Otherwise, the threat of *ex ante* project veto will reduce risk taking.

To summarize, joint liability potentially causes two inefficiencies. Borrowers, unable to credibly commit to sharing their gains when successful, may free-ride on the default insurance provided by their partners. On the other hand, in an effort to stop free-riding, individuals may use approval rights to reduce risk taking and profitability.

3. With full insurance, perhaps enforced through mandatory transfers or an equity-like financial contract, borrowers internalize the cost of coinsurance. This increases risk taking relative to autarky without the free-riding problems of joint liability. When borrowers have identical preferences, the constrained Pareto optimum is obtained.

4. Limited information should weaken cooperation, reducing informal insurance under all contracts. While not explicitly modeled, we expect such reduced cooperation would have the following implications:

   (a) Under individual liability, informal insurance and, as a consequence, risk taking should fall.

   (b) Because the cooperative equilibrium is less valuable and defection harder to detect, free-riding in joint liability will be more likely. The net effect on risk taking will be offset to the extent individuals engage in risk mitigation to prevent joint default.

   (c) Approval rights will more likely be used to prevent risk taking.

4 Experimental Design and Procedures

4.1 Basic Structure

This section describes a series of experiments designed to simulate the economic environment described in Section 3. Subjects were recruited from the clients of Mahasemam, a large microfinance institution in urban Chennai, a city of seven million people in southeastern India. All were women, and their mean reported daily income was approximately Rs. 55 or

$1.22 at then-current exchange rates. Participants earned an average of Rs. 81 per session, including a Rs. 30 show-up fee, and experimental winnings ranged from Rs. 0 to Rs. 250.

Mahasemam organizes its clients into groups of 35 to 50 women called *kendras*. These *kendras* meet weekly for approximately one hour with a bank field officer to conduct loan repayment activities. To recruit individuals for the experiment, I attended these meetings and introduced the experiment. Those interested in participating were given invitations for a specific experimental session occurring within the following week and told that they would receive Rs. 30 for showing up on time.

At the start of each session, individuals played an investment game to benchmark their risk preferences. Subjects were given a choice between eight lotteries, each of which yielded either a high or low payoff with probability 0.5. Panel A of Table 4 summarizes the eight choices.[12] Payoffs in the benchmarking game ranged from Rs. 40 with certainty for choice A to an equal probability of Rs. 120 or Rs. 0 for choice H.

The body of the session then consisted of two to five games, each comprising an uncertain number of rounds. Figure 1 summarizes timing for each round of the stage game. At the start of each game, individuals were publicly and randomly matched with one other participant ($t = 0$ in Figure 1) and endowed with a token worth Rs. 40, which was described as a loan that could be used invest in a project but which needed to be repaid at the end of each round ($t = 1$). Each subject then used the token to indicate her choice from a menu of eight investment lotteries ($t = 2$), after which we collected their tokens. Because many subjects were illiterate, I illustrated the choices graphically as shown in Figure A1. These lotteries were designed to elicit subjects' risk preferences and were ranked according to risk

[12] To determine investment success, subjects played a game where a researcher randomly and secretly placed a black stone in one hand and a white stone in the other. Subjects then picked a hand and earned the amount shown in the color of the stone that they picked (figure A1). Nearly all subjects played a similar game as children in which one player hides a single object, usually a coin or stone, in one of the hands. If the other player guesses the correct hand, they win the object and are allowed to hide the object in her hands. In Tamil, the name is known as either *kandupidi vilayaattu*, which translates roughly as "the find-it game," or *kallu vilayaattu*, "the stone game." Subjects' experience with games similar to the experiment's randomizing device provides some confidence that the probabilities of the game are reasonably well understood.

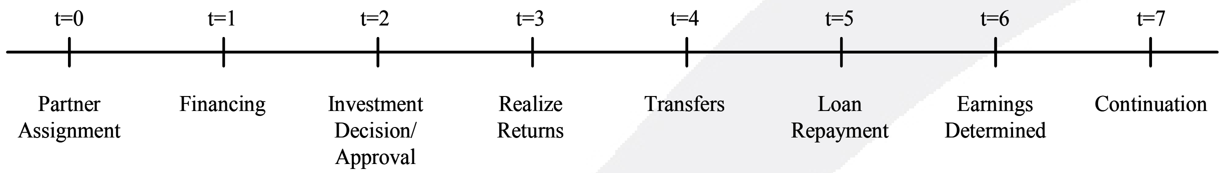

Figure 1: Timing of Events

and return. Payoffs ranged from Rs. 80 with certainty for choice A to an equal probability of Rs. 280 or 0 for choice H; the other choices were distributed between these two. Because expected profits increase monotonically with risk, I use them as a proxy for risk-taking in the discussion below.

We then determined returns for each individual's project and paid this income in physical game money ($t = 3$). Pilot studies suggested that participants understood the game more clearly and payoffs were more salient when the game money was physical and translated one-for-one to rupees. After individuals received their income, they could transfer to their partners any amount up to their total earnings for the period, subject to the rules of the financial contract treatment ($t = 4$). The next subsection describes these financial contract treatments in detail. After transfers were completed, we collected the loan repayment of Rs. 40 from each participant ($t = 5$). Willful default was not possible; if an individual had sufficient funds to repay, she had to repay.

After total earning were calculated ($t = 6$), the game continued with a probability of 75% ($t = 7$). If the game continued, each individual played another round of the same game with the same partner beginning again at $t = 1$.[13] Those who had repaid their loans in the prior period, subject to the terms of the different contract treatments discussed below, received a new loan token and were able to invest again. Those who had been unable to repay in a previous round sat out and scored zero for each round until the game ended. This

[13] I determined if the current game would continue by drawing a colored ball from a bingo cage containing 15 white balls and 5 red. If a white ball was drawn, the game continued. If a red ball was drawn, the game ended.

continuation method simulates the discrete-time, infinite-horizon game described in Section 3 with a discount rate of 33%. The game is also stationary; at the start of any round, the expected number of subsequent rounds in the game was four. When a game ended, loan tokens were returned to anyone who had defaulted and participants were randomly rematched with a different partner. Subject were informed that once a game ended, they would not play again with the same partner. Approximately 75% of participants were matched with a partner from a different *kendra* in order to limit the scope for out-of-game punishment. I included within-*kendra* matches to test the effect of these linkages. At the start of each game, we verbally explained the rules to all subjects and confirmed understanding through a short quiz and a practice round. The Appendix provides an example of the verbal instructions, translated from the Tamil.

At the end of each session, subjects completed a survey covering their occupations and borrowing and repayment experience. The survey also included three trust and fairness questions from the General Social Survey (GSS) and a version of the self-reported risk-taking questions from the German Socioeconomic Panel (SOEP).[14] I then paid each subject privately and confidentially for only one period drawn at random for each individual at the end of the session. This is a key design feature. If every round were included for payoff, individuals could partially self-insure income risk across rounds.[15]

[14]The three GSS questions are the same as those used by Giné, Jakiela, Karlan, and Morduch (2007) and Cassar, Crowley, and Wydick (2007). Back-translated from the Tamil, they are: (1) “Generally speaking, would you say that people can be trusted or that you can’t be too careful in dealing with people?”; (2) “Do you think most people would try to take advantage of you if they got a chance, or would they try to be fair?”; and (3) “Would you say that most of the time people try to be helpful, or that they are mostly just looking out for themselves?” Dohmen, Falk, Huffman, Schupp, Sunde, and Wagner (2006) demonstrates the effectiveness of self-reported questions about one’s willingness to take risks in specific areas (e.g., financial matters or driving) at predicting risky behaviors in those areas. Based on this finding, I asked the following question: “How do you see yourself? As it relates to your business, are you a person who is fully prepared to take risks or do you try to avoid taking risks? Please tick a box on the scale where 0 means ‘unwilling to take risks’ and 10 means ‘fully prepared to take risks.’” Subject were unaccustomed to abstract, self-evaluation questions and had difficulty answering.

[15]See appendix section B.1 for details.

Table 1: Summary of Financial Contract Treatments

	Communi-cation	Dynamic Incentives	Informal Risk Sharing	Joint Liability	Explicit Project Approval	Third-Party Enforced Transfers
Autarky (A)	●	●				
Individual Liability (IL)	●	●	●			
Joint Liability (JL)	●	●	●	●		
Joint Liability with Approval (JLA)	●	●	●	●	●	
Equity (E)	●	●	●	●		●

4.2 Financial Contract Treatments

Using the basic game structure described above, I considered five contract treatments: autarky, individual liability, joint liability, joint liability with approval rights, and equity. Each required loan repayment of Rs. 40 per borrower and included dynamic incentives—subjects failing to meet contractual repayment requirements were unable to borrow in future rounds and earned zero for each remaining round of the game. In all treatments, individuals were allowed to communicate with their partner. While sacrificing a degree of control, I felt communication was an important step towards realism. The five experimental contract treatment described below embody the contracts described in Section 3.

Autarky (A). This treatment comprised individual liability lending without the possibility of income transfers. It captures the key features of dynamic loan repayment and provides a benchmark against which to measure the effect of other contracts and informal insurance on risk-taking behavior. Each subject was paired with another participant and could communicate freely as in all other treatments. Subjects were able to continue play if and only if they were able to repay Rs. 40 after their project return was realized.

Individual Liability (IL). This treatment embedded individual lending in an environment with informal risk-sharing. It followed the same formal contract structure of the autarky treatment but allowed subjects to make voluntary transfers to their partners after project returns were realized and before loan repayment.

Joint Liability (JL). This treatment captures the core feature of most microfinance contracts, joint liability. Members of a pair were jointly responsible for each others' loan repayments. A subject was able to continue play only if both she and her partner repaid Rs. 40. To isolate the effect of the formal contract and minimize framing concerns, instructions for this treatment differed from those for individual liability only in their description of repayment requirements.

Joint Liability with Approval Requirement (JLA). This treatment modifies basic joint liability to require partner approval of investment choices and reflects the assumption, proposed by Stiglitz (1990), that joint-liability borrowers have the ability to force safe project choices on their partners. It differed from the joint liability treatment only in that immediately after participants indicated their project choices, we asked their partner if they approved of the choice. A subject whose partner did not approve her choice was automatically assigned choice A, the riskless option.

Equity (E). In this treatment I enforced an equal division of all income thereby eliminating the commitment problem and the implementability constraint it places on insurance transfers. Participants were able to make additional transfers, and the game was otherwise identical to the joint liability treatment.

4.3 Information Treatments

All of the financial contract treatments except for autarky were played under two information regimes: full and limited information. Much of the literature on microfinance discusses the importance of peer monitoring and local information,[16] and these treatments were designed to see how information affects performance under different contracts. In all treatments, we seated members of a pair together and allowed them to communicate freely. Under **full**

[16] Among the numerous examples are Banerjee, Besley, and Guinnane (1994), Stiglitz (1990), Wydick (1999), Chowdhury (2005), Conning (2005), Armendáriz de Aghion (1999), and Madajewicz (2004).

information, all actions and outcomes were observable. Under **limited information**, we separated partners with a physical divider that allowed communication but prevented them from seeing each other's investment choices and outcomes.[17] After investment outcomes were realized, we informed each participant if her partner had sufficient income to repay her own loan. Transfer amounts were observed only after the transfer was completed. Individuals could not see their partner make the transfer but saw the amount of the transfer once it was made.

5 Experimental Results

In total, I have 3,443 observations from 450 participant-sessions, representing 256 unique subjects. All sessions were run between March 2007 and May 2007 at a temporary experimental economic laboratory in Chennai, India. I conducted 24 sessions, averaging two hours each, excluding time spent paying subjects. As summarized in Table 5, the number of participants per session ranged from 8 and 24, depending on show-ups. The mean was 18.75. Participants were invited to attend multiple sessions, and the number of sessions per participants ranged from 1 to 6, with a mean of 1.75. Summary statistics appear in Table 6.

In the subsections that follow, I separate the experimental results into two categories. Section 5.1 describes the effect of contracts and information on informal risk-sharing. Section 5.2 concerns risk taking and project choice.

[17] Unobservability was successfully enforced with the threat of financial punishment and dismissal from the experiment.

5.1 The Impact of Contracts and Information on Informal Risk-Sharing

RESULT 1. *Actual informal insurance transfers fall well short of full risk-sharing and the maximum implementable informal insurance arrangement with full information. On average, transfers achieve only 14% of full risk-sharing and approximately 30% of the maximum implementable transfer.*

As discussed in Section 3, existing models of informal insurance with limited commitment, including this one, do not make unique predictions for observed transfers. The dynamic game setting admits a multiplicity of equilibria that always includes autarky, i.e., no informal transfers. However there is a natural tendency to focus on the constrained Pareto optimal arrangement, which places an upper bound on the performance of informal insurance and may also represent the outcome of focal strategies (Coate and Ravallion 1993). I calculate constrained Pareto optimal transfers using numerical simulations based on individuals' CRRA risk aversion parameters estimated from benchmark risk experiment, actual project choices for each subject pair, and a static transfer arrangement with equal Pareto weights. These experimental results find observed transfers well below those achieved by either full risk-sharing or at the constrained Pareto optimum.

Columns 1 and 2 of Table 7 summarize net transfers from the partner with higher income under individual liability, joint liability and joint liability with approval. If risk-sharing were complete, these transfers would equal one-half of the difference between payoffs; however, in each case transfers are well below the full risk-sharing benchmark. Joint liability with full information generates the highest net transfers, 5.3, but this is only 27% of the full risk-sharing amount of 19.6. These shortfalls arise along both the extensive and intensive margins. For individual and joint liability contracts with full information, either individual made a transfer in only 50% of all rounds. Under limited information, the probability of any transfer fell to 30%. Furthermore, when transfers were made, they tended to remain well below the full risk-sharing benchmark, as shown in columns 3 and 4 of Table 7. Again, joint liability with full information produces the largest net transfers relative to full insurance, but conditional on any transfer being made they still average only 43% of the full insurance amount. While transfers occur more often under joint liability with approval—in 72% of all rounds with full information and 47% without—net transfers were smaller than those in other contracts.

This result highlights the importance of equilibrium selection. The preponderance of empirical research on informal insurance with limited commitment suggests that actual transfers fall short of full insurance.[18] While this can in part be explained by implementability constraints imposed by limited commitment (Ligon, Thomas, and Worrall 2002), these experimental results suggest that actual informal insurance may settle on an equilibrium well below even the constrained Pareto optimal. One possible explanation, consistent with the results from Charness and Genicot (2007), is that the constrained Pareto optimal may be easier to obtain when there is an obvious focal strategy. In their experiment, transfers were close to theoretically predicted amounts when subjects had identical and perfectly negatively correlated income processes; however, with heterogeneity, actual transfers were substantially below predicted levels and close to those I observed. This calls into question the use of constrained Pareto optimality as the focal selection criteria for informal sharing arrangements. Exploring alternative selection criteria, such as risk-dominance in the sense of Harsanyi and Selten (1988), offers a promising avenue for future research.

Although informal insurance consistently fell short of the theoretical maximum, formal contracts and information greatly influence risk-sharing behavior. The next result points to the importance of information.

RESULT 2. *Informal insurance is substantially larger under full information than when*

[18] See, for example, Townsend's (1994) study of risk and insurance in the ICRISAT villages; Udry's (1994) work on informal credit markets as insurance in northern Nigeria; and Fafchamps and Lund's (2003) study of quasi-credit in the Philippines.

information is limited. On average, transfers under full information are 60% larger than those when information is limited.

Theory predicts that cooperation will be harder to sustain when information is limited. While not explicitly modeled in Section 3, we expect that this weakening of cooperation will be reflected in smaller informal insurance transfers when information is limited. This result is evident in Figure 4 and the summary statistics presented in panel B of Table 6. Empirical support is provided by the simple cell-means regression

$$\tau_{it} = \alpha + \sum_j \beta_j T_j + \varepsilon_{it}, \qquad (1)$$

where τ_{it} is the transfer made by individual i in round t, and T_j is a indicator for the contract and information treatment. Table 8 reports these results. In all contracts, full information generated substantially larger transfers than limited information. The percentage difference was largest under individual liability, where mean transfers increase from 2.42 to 5.83, or 140%, and is substantial in all contracts. F-tests reject the equivalence of treatment dummy coefficients between full and limited information for the individual liability contract at the 1%-level; however, large standard errors make it impossible to reject equivalence in the other contracts. Wilcoxon rank-sum tests reject equivalence at any conventional significance level ($p < 0.0001$) for all contracts.

These results are consistent with theoretical predictions that cooperation is harder to sustain when information is imperfect. The size of this information effect is large. Net transfers under joint liability increase from 12% of full risk-sharing when information is limited to 27% with full information.

I now turn to a specific form of cooperation: transfers made when both members of a pair have sufficient income to repay their loans. These "upside" transfers represent pure insurance.

RESULT 3. *Upside risk-sharing is greater under joint liability, increasing by 40% under full information and more than doubling under limited information.*

We would expect that joint liability and the threat of common punishment would induce loan repayment assistance when one party lacked sufficient funds to repay and the other was able to cover the shortfall. However the impact of joint liability contracts on "upside" transfers, i.e., transfers *excluding* loan repayment assistance and thus representing pure insurance, is theoretically ambiguous. As shown in Proposition 3, joint liability can crowd out informal insurance and thus reduce maximum sustainable transfers; however, there is substantial overlap in the set of sustainable equilibrium transfers in all contract treatments. For example, autarky, no transfers beyond what is contractually required, is an equilibrium strategy under any formal contract. But while the current theory does not predict the behavior of *observed* transfers within the possible set of equilibria, there is intuitive appeal to the notion that comparative statics for observed transfers would move in the same direction as those for the Pareto frontier. This intuition proves incorrect as joint liability substantially increases observed upside risk-sharing.

Table 9 shows the results from the cell-mean regression of upside transfers, i.e., transfers excluding loan repayment assistance, made by individuals in each contract setting when their investments are successful. Upside transfers under joint liability are 3.85 (120%) and 2.94 (40%) larger than transfers under individual liability with limited and full information. These differences are significant at the 1%- and 5%-levels. Much of this difference is driven by risk-tolerant individuals, whose transfers increase by 6.32 (228%) and 6.03 (132%) under joint liability. That risk-tolerant individuals increase their total transfers when successful under joint liability with limited information may be expected given that, as discussed in Result 6, they also take significantly greater risk. As a consequence, their total payoff when successful is larger and they have more to share. They also accrue a greater debt by requiring assistance when their projects fail. However, risk-tolerant individuals' transfers as a percentage of the full risk-sharing amount also increase from 9.7% under individual liability to 17.5% under joint liability. They also increase their upside transfers under full information, which did not increase risk taking. With complete information, risk-tolerant individuals' net transfers as a percentage of full risk-sharing increase from 25.7% to 47.5%.

Joint liability also appears to increase upside transfers made by risk-averse individuals, although this effect is more modest. When information is limited, their transfers increase by 101% from 3.33 to 6.69, and this difference is significant at the 5%-level. With full information, the increase is smaller, 12%, and insignificant, but this from a relatively high base of 6.28 under individual liability with full information.

It is tempting to interpret increased upside transfers by individuals taking greater risk as compensation for the default insurance their partners provide, but several other factors call this interpretation into question. Joint liability increases upside transfers even for those not taking additional risk. Moreover, when information is limited, transfers do not appear to increase with the amount of risk imposed. Panel A of Figure 5 shows mean transfers made at each payoff level. Note that transfers at payoff levels of 180 and above, each of which resulted from investments with potential default costs, do not differ from those made at a payoff of 160, the result of a successful investment in project D, which has no default risk. Transfers are flat above 160, even though the potential cost of default increases with the potential gain.

RESULT 4. *Informal insurance transfers are treated like debt; cumulative net transfers received to date are a strong predictor of net transfers made in the current period.*

The model presented in Section 3 solved for mutual insurance arrangements with a restriction to stationary transfers, that is, whenever the same state occurs, the same net transfer is made independent of past histories. As Kocherlakota (1996) and Ligon, Thomas, and Worrall (2002) demonstrate, a "dynamic" limited commitment model may improve welfare relative to the stationary model by promising additional future payments to relax incentive compatibility constraints on transfers in the current period. In practice, such dynamic transfer schemes may be implemented through informal loans as described in Eswaran and Kotwal (1989), Udry (1994) and Fafchamps and Lund (2003).

I test formally for this effect by regressing transfers in each round after the first on payoffs, cumulative net transfers, and the first period transfers of both individuals:

$$\tau_{it} = \alpha_i + \beta_1 y_{it} + \beta_2 y_{-it} + \delta \sum_{\theta=1}^{t-1} (\tau_{it} - \tau_{-it}) + \varepsilon_{it}, \quad (2)$$

where τ_{it} is the transfer made by individual i in round t, y_{it} is individual i's income in round t, and individual fixed effects, α_i, are included to capture subjects' predisposition towards making transfers. If transfers are treated as debt to be repaid, we expect $\delta < 0$.

As shown in panel A of Table 10, the coefficient on cumulative net transfers made is consistently negative—ranging from -0.120 to -0.302—and significant at the 1%-level. These results imply, for example, that under joint liability with limited information we would expect an individual who received the same payoff as her partner and had previously received Rs. 20 of net transfers to make a net transfer of Rs. 5.[19]

5.2 The Impact of Contracts and Information on Risk Taking

I now turn to the effect of contracts and information on risk taking behavior. As described above, expected profits serve as a proxy for risk taking and increase monotonically from 40 for the riskless choice, A, to 120 for the riskiest choice, H. Panel B of Table 4 describes each of the eight project choices.

Figure 3 summarizes risk-taking levels relative to autarky across the contract and informa-

[19] This interpretation is also supported by participants' qualitative responses. For example, after pairing were dissolved and partners rematched, one participant asked explicitly, "I loaned my partner Rs. 20 to repay her debt in the last round. How can I get it back now?"

tion treatments. The illustrated values are calculated from the simple cell-means regression

$$\tilde{y}_{it} = \alpha + \sum_j \beta_j T_j + \varepsilon_{it}, \qquad (3)$$

where $\tilde{y}_{it}$ is the expected profit of individual i's project choice in round t, and T_j is a indicator for the contract and information treatment. Table 11 presents the full results from this estimation.

RESULT 5. *Informal insurance does not increase risk taking.*

As shown in Proposition 1, informal insurance should induce members of a pair to take additional risk. Using the parameters of the experimental setting, I calculated individuals' optimal investment choices under autarky and with informal insurance that achieves the constrained Pareto optimum. The numerical results imply that constrained-efficient insurance should increase risk-taking, as measured by the expected profit of individuals' project choices, by between Rs. 5 and Rs. 10, or 10% to 20%.

Comparing investment choices in the individual liability treatment to those under autarky provides an immediate test of this hypothesis; the individual liability treatment differed from autarky only in that subjects were able to engage in informal risk-sharing. As is evident from Figure 3, the availability of informal insurance had little effect on individuals' risk taking behavior. Neither of the individual liability coefficients from the estimation of (3) are significant as shown in panel A of Table 11. We can reject at the 5%-level increases of 1.2% and 3.2% in the limited and full information treatments.

Given the relatively low levels of informal risk-sharing actually observed, this outcome is perhaps not surprising. While the experiments were designed such that the maximum implementable informal risk-sharing arrangement would increase the optimal contract choice by at least one class (e.g., the optimal contract pair for two individuals with CRRA utility and ρ of 0.5 would move from the pair $\{B, B\}$, with individual payoffs of 100 or 70, in autarky to $\{C, C\}$, with individual payoffs of 140 or 50, under individual liability with informal insurance), the realized levels of informal insurance support only a small increase in risk taking.

The available of informal insurance may also have made risk more salient and thus discouraged risk taking. While communication was allowed in all treatments, participants in the autarky treatment rarely spoke to one another. Under individual liability with informal insurance, participants often discussed their project choices and occasionally made contingent transfer plans. These discussions typically focused on what would happen in the event of a bad outcome and, by making this state more salient, may have discouraged risk taking.

RESULT 6. *The effect of joint liability on risk taking depends on the information environment. Under full information, joint liability marginally reduces risk taking relative to individual liability. With limited information, joint liability increases aggregate risk taking as more risk-tolerant individuals take significantly greater risk, relying on their partners to insure against default.*

Theory does not make sharp predictions for the effect of joint liability on investment choice. On one hand, risk-pooling and mandatory transfers from one's partner encourage risk taking. On the other hand, the threat of joint default may induce risk mitigation and reduce risk-taking. Which effect dominates in practice depends on the risk tolerance of both partners and the selected equilibrium of the dynamic game. In light of the relatively larger amount of informal insurance observed in joint liability relative to individual liability, particularly under full information, we would expect greater risk-taking under joint liability. Under joint liability with limited information, we would expect a more modest increase in risk-taking if individuals are behaving cooperatively; however, if cooperation breaks down, the free-riding effect described in Section 3 would dominate.

In the experiment under full information, joint liability marginally reduces risk taking relative to individual liability. Expected profits fall by 2.8% (1.43). This result, shown in panel B of Table 11, is consistent with the finding that increased communication between partners tends to decrease risk taking, but it is not statistically significant.

Under limited information, the effect is reversed. Joint liability increases risk taking by 3.7% (1.87; $p = 0.012$) relative to individual liability. However in neither case is the Wilcoxon rank-sum test significant; $p = 0.204$ and $p = 0.121$.

Within the joint liability contract, the effect of information on risk taking is pronounced. Limited information increases risk taking by 4.3% (2.17; $p = 0.009$) and the Wilcoxon rank-sum test easily rejects equivalence ($p = 0.001$). Large differences in behavior across risk types drives this increase. Risk-averse individuals respond little to joint liability regardless of the information structure, while more risk-tolerant individuals take significantly greater risk when information is limited.

I divide subjects into risk categories based on their choices in the risk benchmarking games. Approximately 70% of subjects picked one of the safe choices, A through D, and are categorized as “risk averse.” The remaining 30% picked choices E through H and are categorized as “risk tolerant.” This division corresponds to a coefficient of risk aversion of 0.44 for individuals with CRRA utility and a wealth of zero.

When information is complete, joint liability does not appear to affect the investment choices of risk-tolerant individuals. In fact, as shown in column 4 of Table 12, they take less risk than in autarky and their project choices are statistically indistinguishable from those of risk-averse individuals. This is consistent with Giné, Jakiela, Karlan, and Morduch’s (2007) finding that participants who tend to take risks reduce their risk-taking when their partners make safer choices.

When information is limited, risk-tolerant individuals increase their risk taking under the simple joint liability contract. As can be seen in column 2 of Table 12, the mean expected return for risk-tolerant individuals increases by 26% (1.2σ) from 51.3 under individual liability to 64.7 under joint liability. A nonparametric Wilcoxon rank test show this difference is significant at any conventional level ($p < 0.0001$).[20] Evidence of compensatory transfers is mixed. As discussed above, risk-tolerant individuals *do* make larger transfers under joint liability, but two facts call into question the intent of these transfers. First, as can be seen in panel B of Table 9, this increase appears in both full and limited information, while increased risk taking is only evident when information is limited. Second, as shown in Figure 5, there is no discernible differences in transfers by risky individuals who chose projects just below the potential threshold for default (projects C and D) and those who forced their partners to insure against default (projects E, F, G and H). One interpretation of this result is that risk-tolerant individuals increase transfers under joint liability to compensate their partners for the option value of default insurance *even* if their investment choices render this insurance moot. Further experimentation would be useful to test this hypothesis.

Consistent with theoretical predictions, cooperation appears easier to sustain when information is complete. When cooperation breaks down, we expect individuals to take action to discourage free-riding. The next result shows that explicit approval rights are used *ex ante* to discourage risk taking.

RESULT 7. *Explicit approval rights are used to curtail risk taking under joint liability with limited information but have a negligible effect under full information.*

As described in Section 3, explicit approval rights could be used either as a threat to provide additional punishment support for cooperation or actively to prevent risk taking *ex ante*. As shown in panel C of Table 11, the risk-discouragement effect dominates, particularly when information is limited. When information is limited, risk taking in the JLA contract is 6.3% lower than in autarky and 8.3% lower than under joint liability without explicit approval. Both differences are significant at greater than the 1%-level. This effect is concentrated among risk-tolerant individuals, for whom expected profits fall 22% from 63.8

[20] This result is robust to moving the definition of "risk tolerant" up or down one risk class. A fully non-parametric specification for the effect of benchmarked investment choice on risk-taking under joint liability with limited information shows noticeable break between those who elected a "safe" choice in the benchmarking rounds and those who did not.

to 49.9. Risk-averse individuals also reduce their risk relative to individual or joint liability, but the effect is more modest and only borderline significant.

As expected, joint liability creates two potential inefficiencies: free-riding when the enforcement mechanisms necessary to sustain cooperation are weak *and* excessive caution when these mechanisms are strong. The next result turns to one possible solution: equity-like contracts under which full risk-sharing is enforced by a third-party.

RESULT 8. *Equity increases expected returns relative to other contracts while producing the lowest default rates. Under limited information, expected profits are 5% larger than under individual liability and 10% larger than under joint liability with approval rights. While expected profits are only slightly larger than under joint liability, the increased willingness to take risk is distributed across individuals and not the result of risk-tolerant individuals free-riding on their partners.*

Third-party enforcement of equal income distribution overcomes much of the commitment problem associated with informal risk-sharing arrangements. As such, we would expect equity-like contracts to encourage greater risk taking than under autarky or contracts where limited commitment reduces the sustainable amount of insurance.

This result can be seen in Figure 3 and the summary of expected profits by contract type in Table 11. Formal statistical evidence is provided by the regression described in (3). Tests for the equivalence of the equity treatment dummy coefficients against those for individual, joint liability, and joint liability with approval are each significant at better than the 5%-level. Wilcoxon tests reject equivalence at better than the 1%-level in each case. While statistically significant and practically meaningful, the differences in risk taking between equity and individual liability or autarky are less than we would expect. Numerical simulations based on benchmarked risk-taking behavior predict expected profits under the equity contract should increase by 10% to 20% relative to autarky. Actual expected profits increase by 2% to 5%, approximately 0.10 to 0.25 standard deviations. Relative to joint liability with approval rights, the increase in expected profits from equity contracts is more than twice as large, 5% under full information and 10% under limited information.

Panel C of Table 6 reports default rates for each contract, ranging from a high of 4.8% in autarky to 0% under equity. The low default rates are consistent with the reported rates of most microfinance institutions—Mahasemam itself reports client defaults of less than 1%—but since the terms of default were set by the experiment, I focus on relative performance across the contract treatments.[21] Default rates follow the pattern we would expect. Adding informal transfers (moving from autarky to the individual liability treatment) reduces default rates by two percentage points from 4.83% to 2.80%. Moving from individual to joint liability further reduces default rates to 1.35%, or 1.51% when approval rights are explicit. Finally, equity generated no defaults as increased risk was almost always hedged across borrowers, with the worst possible joint outcome still sufficient for loan repayment. Each of the differences in default rates is significant at the 5%-level.

While these experiments abstracted from key challenges for implementing equity contracts, including moral hazard over effort and costly state verification, the results are encouraging. Innovative financial contracts may encourage substantial increases in the expected returns of microfinance-funded projects. However, further research is required to understand why observed risk-taking under the equity contract remained below what would be predicted based on individuals' benchmarked risk preferences. Based on the results of this experiment, exploration of how social factors influence decisions under uncertainty could provide important information on how to most effectively move from the lab to equity-like contracts in the field.

[21] Low levels of reported default suggests that willful default is not prevalent.

6 Conclusion

This paper has developed a theory of risk taking and informal insurance in the presence of formal financial contracts designed to answer the questions: How do microfinance borrowers choose among risky projects? How do they share risk? And how do formal financial contracts affect these behaviors? To shed further light on these questions, it examined the results of a lab experiment that captured the key elements of the theory using actual microfinance clients in India as subjects.

The experiment uncovered a number of interesting results. First, informal insurance falls well short of not only the full risk-sharing benchmark but also the constrained optimal insurance arrangement predicted by theory. This calls into question the use of constrained Pareto optimality as the focal equilibrium selection criteria for informal sharing arrangements. Exploring alternative selection criteria, such as risk-dominance in the sense of Harsanyi and Selten (1988) and Carlsson and van Damme (1993), offers a promising avenue for future research.

Second, in contrast to theoretical predictions, joint liability did not crowd out informal insurance. Upside income transfers, those not required for loan repayment, were almost twice as large under joint liability as under individual lending. This result cannot be explained as compensation for default insurance—increased transfers are evident even among those who did not take additional risk. Joint liability may have increased the perceived social connection to one's partner, thus moving the equilibrium insurance arrangement towards the constrained Pareto optimum. Or joint liability may have provided a coordination device that facilitated implementation of cooperative transfer arrangements. A definitive explanation is beyond the scope of the available experimental evidence, and further research is necessary to distinguish the social effects, coordination devices, and other explanations.

Third, despite the apparent value attached to joint liability, when information was imperfect, such contracts still produced significant free-riding. Risk-tolerant individuals took substantially greater risk without compensating their partners for the added insurance burden. Granting approval rights eliminated free-riding but also reduced risk-taking below autarky levels. The strength of this effect suggests that peer monitoring may not only reduce *ex ante* moral hazard but also discourage risk taking more generally, regardless of efficiency. Combined with the result that informal insurance had a negative, though statistically insignificant, effect on risk taking, this result suggests research into social determinants of investment choice would be fruitful and may explain the lack of demonstrable growth in microfinance-funded enterprises.

Finally, equity increased risk-taking and expected returns relative to other financial contracts, although these increases were less than half what theory would predict for optimal behavior. At the same time, equity also generated the lowest default rates. While there are significant hurdles to implementing such contracts in practice and further research is required to understand deviations from predicted risk-taking behavior, these results are encouraging and suggest that equity-like contracts merit further exploration in the field.

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Figure 2: Illustration of Joint Liability Static Investment Choice Effects

Best Response Function for Individual B: S=1, R=3, D=1, β=0.75, π=0.5

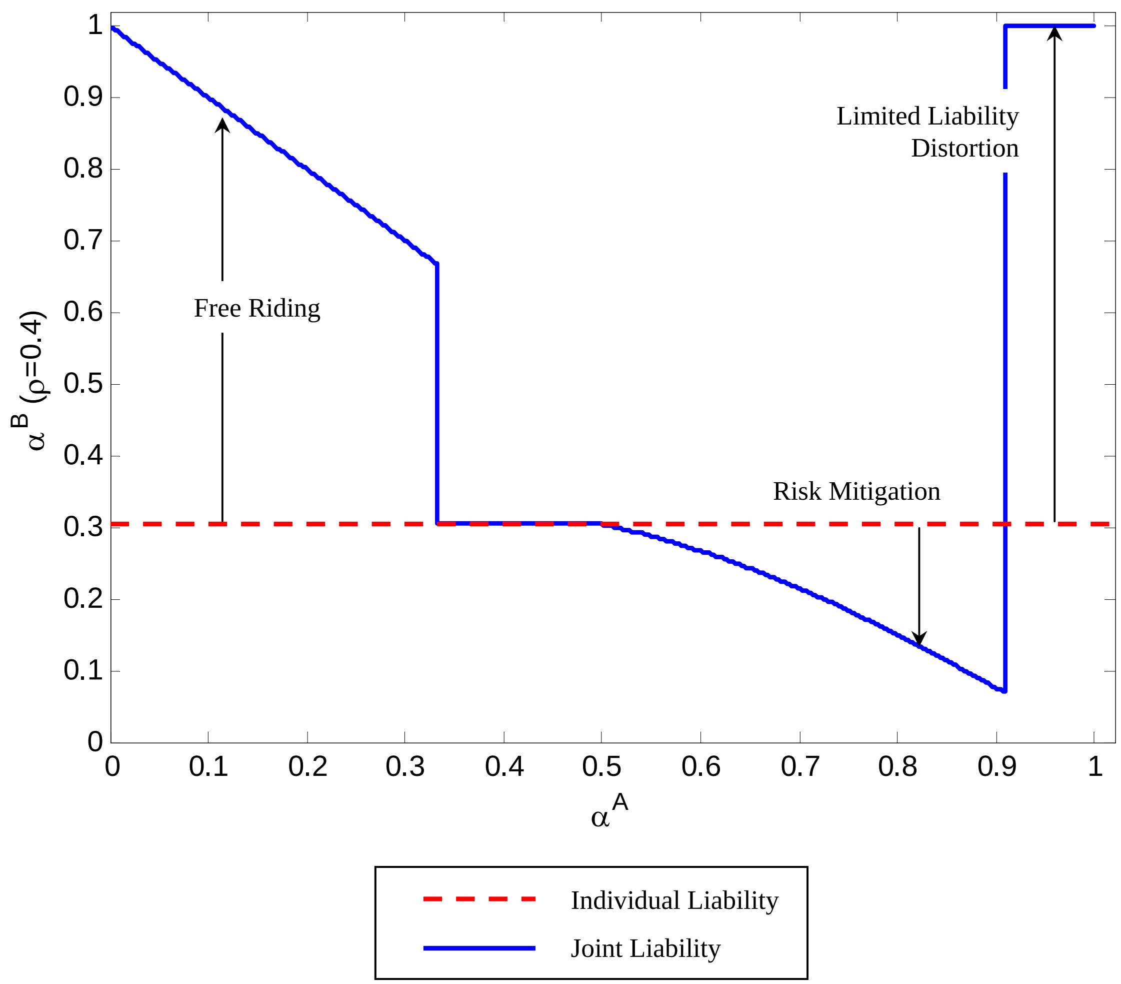
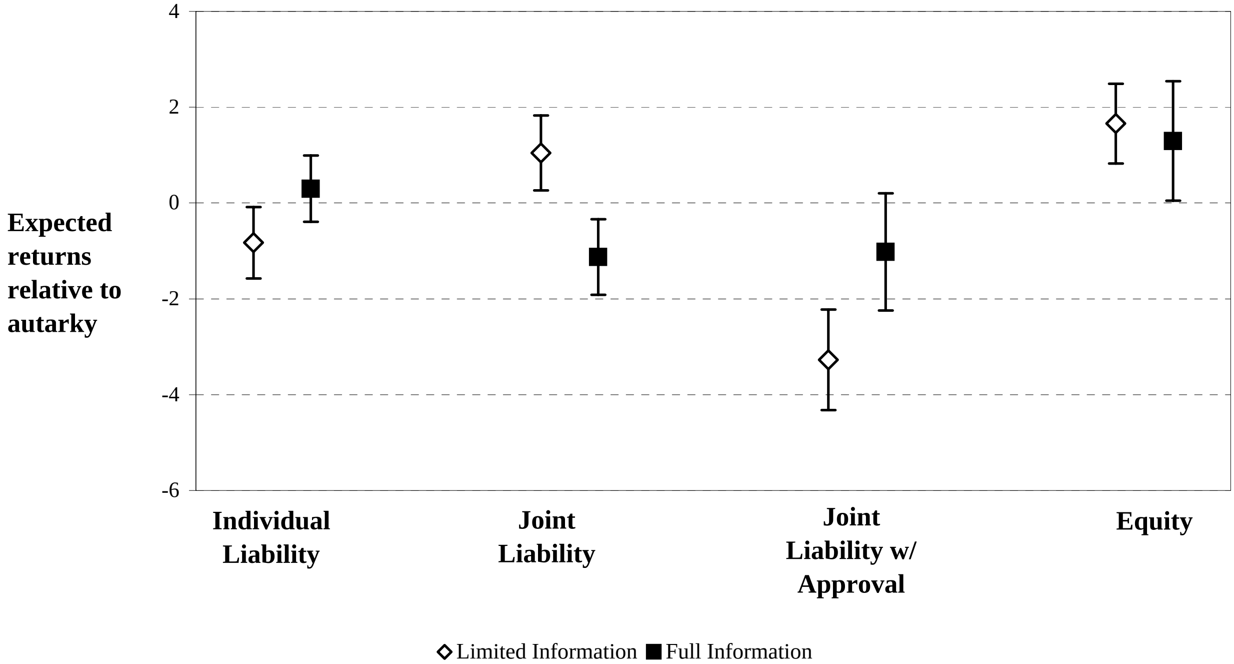


Figure 3: Risk Taking by Treatment



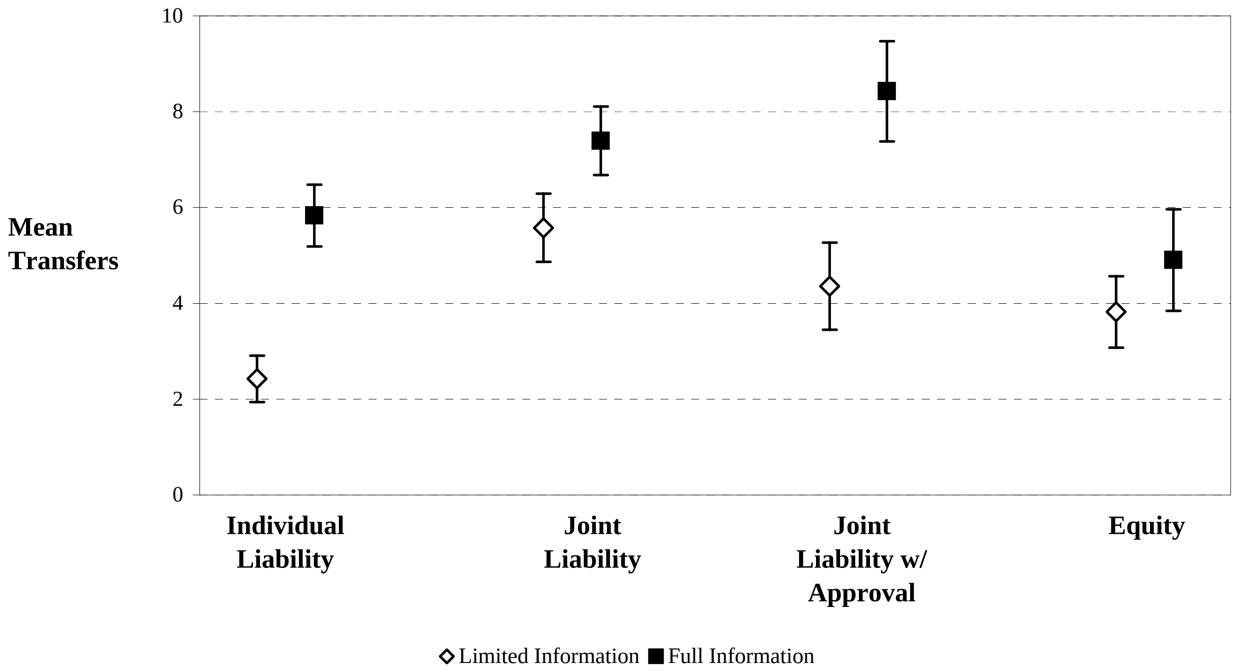
Notes:

(1) Relative expected returns proxy for risk-taking behavior as expected returns increase monotonically in a project's riskiness. Plot points represent coefficients on treatment dummies in the regression $\text{ProjProfit}_i = \alpha + \sum_j \beta_j T_j + \varepsilon_i$

(2) Mean expected returns in autarky equal Rs. 51.2.

(3) Error bars represent one standard deviation.

Figure 4: Mean Transfers by Treatment



Notes:

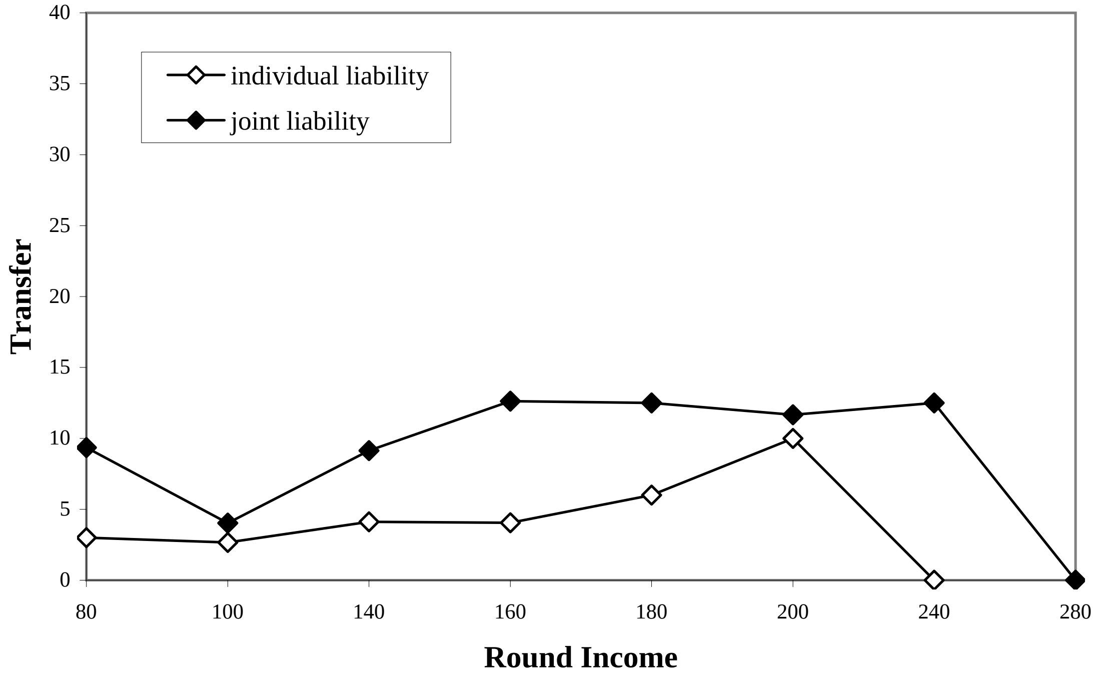
(1) Plot points represent coefficients on treatment dummies in the regression $\text{transfer}_i = \sum_j \beta_j T_j + \varepsilon_i$

(2) Error bars represent one standard deviation.

(3) Equity transfers exclude mandatory, third-party-enforced transfers.

Figure 5: Transfers by Round Income

A. Limited Information



B. Full Information

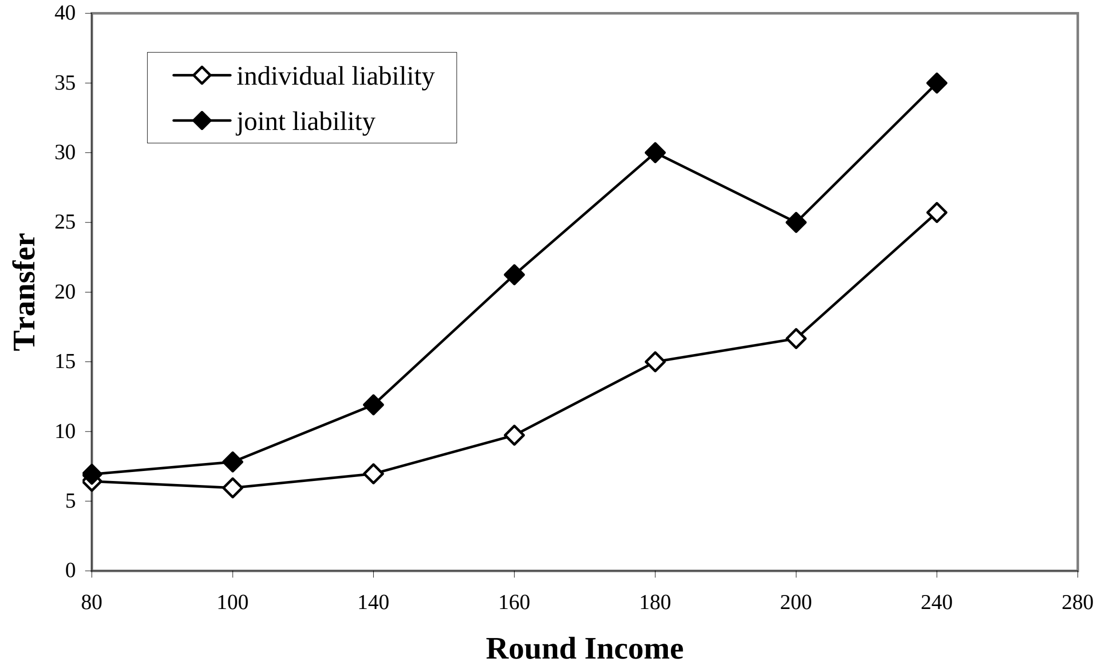


Table 2: Maximium Sustainable Transfers

Transfer when outcome is {h,l}

A. DYNAMIC INCENTIVES (future borrowing conditional on current repayment)

Choice Pair	Full Insurance	CRRA risk aversion index (ρ) 0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
{A,A}	0	0	0	0	0	0	0	0	0
{B,B}	15	0	0	0	0	0	0	0	0
{C,C}	45	0	0	4	16	26	36	43	45
{D,D}	60	5	21	42	60	60	60	60	60
{E,E}	75	61	72	75	75	75	75	75	75
{F,F}	90	67	79	90	90	90	90	90	90
{G,G}	115	81	97	115	115	115	115	115	115
{H,H}	140	96	115	138	140	140	140	140	140

B. NO DYNAMIC INCENTIVES (borrowing available every period)

Choice Pair	Full Insurance	CRRA risk aversion index (ρ) 0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
{A,A}	0	0	0	0	0	0	0	0	0
{B,B}	15	0	0	0	0	0	0	0	0
{C,C}	45	0	0	4	16	26	36	43	45
{D,D}	60	5	21	42	60	60	60	60	60
{E,E}	75	0	0	28	65	75	75	75	75
{F,F}	90	0	0	0	64	90	90	90	90
{G,G}	115	0	0	0	67	115	115	115	115
{H,H}	140	0	0	0	0	140	140	140	140

Table 3: Average Per Period Utility

A. AUTARKY

Choice Pair	CRRA risk aversion index (ρ)							
	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
{A,A}	23.9	18.9	15.2	12.6	10.9	10.1	10.5	14.5
{B,B}	26.0	20.3	16.1	**13.2**	**11.3**	**10.3**	**10.6**	**14.6**
{C,C}	**28.8**	**21.5**	**16.5**	13.2	11.0	10.0	10.2	14.2
{D,D}	28.8	20.4	14.7	11.0	8.5	7.0	6.5	8.1
{E,E}	13.0	9.1	6.5	4.7	3.6	2.9	2.7	3.3
{F,F}	14.5	10.0	7.0	5.1	3.8	3.1	2.8	3.3
{G,G}	17.3	11.7	8.0	5.7	4.2	3.3	2.9	3.4
{H,H}	20.1	13.2	8.9	6.2	4.5	3.5	3.0	3.5

B. FULL INSURANCE

Choice Pair	CRRA risk aversion index (ρ)							
	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
{A,A}	23.9	18.9	15.2	12.6	10.9	10.1	10.5	14.5
{B,B}	26.2	20.4	16.2	13.3	11.4	10.4	10.7	**14.6**
{C,C}	29.8	22.6	**17.5**	**14.0**	**11.7**	**10.5**	**10.7**	14.6
{D,D}	**30.9**	**22.7**	17.1	13.2	10.7	9.2	8.9	11.6
{E,E}	19.4	14.1	10.4	8.0	6.4	5.4	5.2	6.7
{F,F}	21.0	15.1	11.1	8.4	6.6	5.6	5.3	6.7
{G,G}	24.9	17.5	12.6	9.3	7.2	5.9	5.5	6.9
{H,H}	28.5	19.7	13.9	10.1	7.7	6.3	5.7	7.0

C. MAXIMUM SUSTAINABLE TRANSFERS

Choice Pair	CRRA risk aversion index (ρ)							
	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
{A,A}	23.9	18.9	15.2	12.6	10.9	10.1	10.5	14.5
{B,B}	26.0	20.3	16.1	13.2	11.3	10.3	10.6	14.6
{C,C}	28.8	21.5	16.7	**13.7**	**11.6**	**10.5**	**10.7**	**14.6**
{D,D}	**29.5**	**22.1**	**17.0**	13.2	10.7	9.2	8.9	11.6
{E,E}	19.3	14.1	10.4	8.0	6.4	5.4	5.2	6.7
{F,F}	20.9	15.1	11.1	8.4	6.6	5.6	5.3	6.7
{G,G}	24.7	17.4	12.6	9.3	7.2	5.9	5.5	6.9
{H,H}	28.3	19.6	13.9	10.1	7.7	6.3	5.7	7.0

Note: Bold and boxed amount represents maximum per period utility.

Table 4: Summary of Investment Choices

A. BENCHMARKING GAME

Choice	Payoffs: White (High)	Payoffs: Black (Low)	Expected Round Profit	Risk Aversion Coefficient
A	40	40	40.0	1.76 to ∞
B	60	30	45.0	0.81 to 1.76
C	70	25	47.5	0.57 to 0.81
D	80	20	50.0	0.44 to 0.57
E	90	15	52.5	0.34 to 0.44
F	100	10	55.0	0.26 to 0.34
G	110	5	57.5	0.17 to 0.26
H	120	0	60.0	−∞ to 0.17

B. CORE GAMES (all include debt repayment)

Choice	Payoffs: White (High)	Payoffs: Black (Low)	Expected Round Profit (1)	Implied Risk Aversion Coeff. in Autarky(2): Single Shot	Implied Risk Aversion Coeff. in Autarky(2): Dynamic(3)
A	80	80	40.0	6.2 to ∞	3.9 to ∞
B	100	70	45.0	0.59 to 6.20	1.0 to 3.9
C	140	50	55.0	-----	0.57 to 1.0
D	160	40	60.0	-----	−∞ to 0.57
E	180	30	70.0	-----	-----
F	200	20	80.0	-----	-----
G	240	10	100.0	-----	-----
H	280	0	120.0	−∞ to 0.59	-----

Notes:

(1) After debt repayment of Rs. 40.

(2) Assumes wealth level of zero.

(3) Continuation probability equals 75%. Default round income equals zero.

Table 5: Session Detail

A. SESSION SUMMARY

Session	Date	Rounds	Participants
1	4/09/2007	5	24
2	4/10/2007	9	23
3	4/11/2007	12	16
4	4/13/2007	7	20
5	4/18/2007	6	14
6	4/23/2007	11	8
7	4/24/2007	9	22
8	4/25/2007	12	10
9	4/26/2007	7	21
10	4/27/2007	9	21
11	4/30/2007	7	20
12	5/01/2007	10	18
13	5/03/2007	12	15
14	5/04/2007	11	20
15	5/07/2007	10	20
16	5/08/2007	15	20
17	5/09/2007	11	17
18	5/10/2007	14	17
19	5/14/2007	11	23
20	5/15/2007	10	24
21	5/16/2007	11	17
22	5/17/2007	9	20
23	5/18/2007	10	20
24	5/21/2007	13	20

B. OBSERVATION COUNTS BY GAME

	Information		
Game	Full	Limited	Total
Benchmarking	--	--	341
Debt in autarky	--	--	768
Individual liability	420	520	940
Joint Liability	352	336	688
Joint liabilty with partner approval	172	110	282
Equity	318	106	424

Table 6: Summary Statistics

	Information[2] Limited (1)	Information[2] Full (2)	Total (2)
A. RISK-TAKING (measured by expected profits)			
Autarky			51.64 (12.42) [812]
Individual Liability	50.33 (9.71) [396]	51.46 (13.81) [498]	50.96 (12.17) [894]
Joint Liability	52.20 (11.85) [338]	50.03 (11.56) [330]	51.13 (11.75) [668]
Joint Liability w/ Partner Approval	47.88 (8.37) [156]	50.14 (9.63) [108]	48.81 (8.96) [264]
Equity	52.82 (14.09) [284]	52.45 (10.70) [104]	52.72 (13.25) [388]
B. TRANSFERS			
Individual Liability	2.42 (6.24) [396]	5.83 (10.94) [498]	4.32 (9.31) [894]
Joint Liability	5.58 (13.41) [338]	7.39 (11.27) [330]	6.47 (12.42) [668]
Joint Liability w/ Partner Approval	4.36 (6.81) [156]	8.43 (7.93) [108]	6.02 (7.55) [264]
Equity[3]	4.21 (6.77) [228]	4.90 (5.95) [104]	4.43 (6.52) [332]

Notes:
(1) Standard deviations in parentheses. Observation counts in brackets.
(2) In full information treatment, all actions and payments are observable. In limited information treatment, all partner's actions are unobservable. Players are informed only if partner earned enough to repay her debt, Rs. 40.
(3) Excludes mandatory, third-party enforced transfers.

Table 6: Summary Statistics (cont)

	Information(2) Limited	Full	Total
	(1)	(2)	(2)
C. DEFAULT RATES			
Autarky			4.80%
			(0.21)
			[812]
Individual Liability	2.27%	3.21%	2.80%
	(0.15)	(0.18)	(0.16)
	[396]	[498]	[894]
Joint Liability	1.48%	1.21%	1.35%
	(0.12)	(0.11)	(0.12)
	[337]	[330]	[667]
Joint Liability w/ Partner Approval	1.28%	1.83%	1.51%
	(0.11)	(0.13)	(0.12)
	[156]	[109]	[265]
Equity	0.00%	0.00%	0.00%
	(0.00)	(0.00)	(0.00)
	[284]	[104]	[388]
D. AVERAGE NET INCOME PER ROUND			
Autarky			47.79
			(42.44)
			[869]
Individual Liability	49.74	48.37	48.98
	(37.82)	(37.92)	(37.86)
	[409]	[510]	[919]
Joint Liability	52.39	49.03	50.75
	(41.87)	(32.42)	(37.56)
	[352]	[336]	[688]
Joint Liability w/ Partner Approval(3)	41.10	54.18	46.21
	(27.96)	(38.69)	(33.12)
	[172]	[110]	[282]
Equity(3)	48.77	40.96	46.68
	(31.29)	(29.54)	(30.99)
	[284]	[104]	[388]

Notes:

(1) Standard deviations in parentheses. Observation counts in brackets.

(2) In full information treatment, all actions and payments are observable. In limited information treatment, all partner's

(3) The project success rate for full risk sharing treatment in the full and limited information settings was 37.1% and 46.9%. The project success rate for joint liability with partner approval was 57.9%. All equal 50% in expectation.

Table 7: Net Transfers as Percentage of Full Transfers

Net transfers from partner with higher income

	All		Conditional on Any Transfer	
	Information		Information	
	Limited	Full	Limited	Full
	(1)	(2)	(3)	(4)
Individual Liability				
Net Transfers	1.3	3.6	7.0	7.7
Full Risk Sharing Transfer	19.1	20.3	23.5	22.5
Net as % of Full	6.9%	17.5%	29.8%	34.2%
Joint Liability				
Net Transfers	3.2	5.3	11.1	10.3
Full Risk Sharing Transfer	25.4	19.6	32.2	24.2
Net as % of Full	12.5%	27.2%	34.6%	42.7%
Joint Liability with Approval				
Net Transfers	-0.3	1.3	2.2	1.6
Full Risk Sharing Transfer	14.9	19.0	18.1	19.2
Net as % of Full	-1.7%	6.8%	12.1%	8.3%

Notes:

(1) In full information treatment, all actions and payments are observable. In limited information treatment, all partner's actions are unobservable. Players are informed only if partner earned enough to repay her debt, Rs. 40.

(2) Full risk sharing transfer equals (own payoff - partner's payoff)/2

Table 8: Effect of Contract Type & Information on Transfers

OLS Regression of Transfers on Treatment Dummies

$$\text{Transfer}_i = \alpha + \sum_j \beta_j T_j + \varepsilon_i$$

	Limited Information[2] (1)	Full Information[2] (2)	Difference Lim - Full (3)
A. COEFFICIENT ESTIMATES			
Individual liability	- -[1]	3.41***	-3.41***
		(0.99)	
Joint liability	3.15***	4.97**	-1.82
	(0.88)	(1.95)	(2.08)
Joint liability w/ approval	1.93***	6.00**	-4.07
	(0.46)	(2.60)	(2.58)
Equity[3]	1.40*	2.48***	-1.08
	(0.78)	(0.83)	(0.69)
B. TREATMENT EFFECTS RELATIVE TO JOINT LIABILITY			
Individual	-3.15***	-1.56	
	(0.88)	(1.88)	
Joint liability w/ approval	-1.22	1.03	
	(0.80)	(3.21)	
Equity[3]	-1.76**	-2.49	
	(0.87)	(2.06)	
C. TREATMENT EFFECTS RELATIVE TO JOINT LIABILITY w/ APPROVAL			
Individual	-1.93***	-2.59	
	(0.46)	(2.47)	
Equity[3]	-0.54	-3.52	
	(0.70)	(2.68)	

Notes:

(1) Omitted Category: Individual Liability, Limited Information; Mean transfers: 2.42

(2) In full information treatment, all actions and payments are observable. In limited information treatment, all partner's actions are unobservable. Players are informed only if partner earned enough to repay her debt of Rs. 40.

(3) Excludes mandatory, third-party enforced transfers. Including these, total average transfers for the equity treatment under limted and full information are 13.10 and 14.31.

(4) Session clustered standard errors in parenthses. * denotes significance at the 10%, ** at the 5%, and *** at the 1% level.

Table 9: Effect of Contract Type & Information on Upside Sharing

Transfers When Project Suceeds, Excluding Debt Repayment Assistance

$$\text{UpsideTransfer}_i = \sum_j \beta_j T_j + \varepsilon_i$$

	Limited Information (1)	Full Information (2)	Difference Lim - Full (3)
A. ALL			
Individual liability	3.21	6.70	-3.49***
	(0.35)	(0.85)	(0.92)
Joint liability	7.06	9.65	-2.58
	(0.82)	(2.59)	(2.72)
Joint liability w/ approval	4.70	9.27	-4.57***
	(0.35)	(1.37)	(1.41)
Difference: Joint - Individual	3.85***	2.94	
	(0.90)	(2.53)	
B. RISK TOLERANT SUBJECTS			
Individual liability	2.77	4.59	-1.82
	(0.81)	(0.92)	(1.23)
Joint liability	9.09	10.63	-1.53
	(4.97)	(4.10)	(6.44)
Joint liability w/ approval	6.36	9.50	-3.14
	(2.06)	(0.29)	(2.08)
Difference: Joint - Individual	6.32	6.03	
	(4.84)	(4.18)	
C. RISK AVERSE SUBJECTS			
Individual liability	3.33	6.28	-2.95*
	(0.29)	(1.74)	(1.77)
Joint liability	6.69	7.05	-0.36
	(0.98)	(3.22)	(3.37)
Joint liability w/ approval	4.20	10.14	-5.94***
	(0.32)	(0.82)	(0.88)
Difference: Joint - Individual	3.36***	0.77	
	(1.07)	(3.45)	

Notes:

(1) Standard errors clustered at the session level in parentheses.

(2) In full information treatment, all actions and payments are observable. In limited information treatment, all partner's actions are unobservable. Players are informed only if partner earned enough to repay her debt of Rs.

(3) Risk tolerant and risk averse classifications based on benchmark risk experiments

(4) * Denotes significance at the 10%-level, ** at the 5%-level, and *** at the 1% level.

Table 10: Determinants of Transfer Behavior

	Individual Liability		Joint Liabilty		Joint Liabilty w/ App.	
	Limited	Full	Limited	Full	Limited	Full
	(1)	(2)	(3)	(4)	(5)	(6)
Transfers						
Own income (β_1)	0.033***	0.059***	0.048***	0.108***	0.040***	0.009
	(0.005)	(0.007)	(0.008)	(0.018)	(0.015)	(0.054)
Partner's income (β_2)	-0.009	-0.006	-0.025***	-0.028***	-0.013*	-0.024
	(0.009)	(0.014)	(0.009)	(0.006)	(0.007)	(0.052)
Cumulative net transfers (δ)	-0.120***	-0.186**	-0.247***	-0.189***	-0.302***	-0.162***
	(0.025)	(0.089)	(0.079)	(0.021)	(0.001)	(0.004)
Observations	396	498	338	330	156	108
R^2	0.41	0.59	0.75	0.65	0.64	0.64
Mean transfers	2.42	5.83	5.58	7.39	4.36	8.43

Notes:

(1) Standard errors clustered at the session level in parentheses. Includes individual fixed effects.

(2) In full information treatment, all actions and payments are observable. In limited information treatment, all partner's actions are unobservable. Players are informed only if partner earned enough to repay her debt, Rs. 40.

Table 11: Effect of Contract Type & Information on Risk Taking

OLS Regression of Expected Profits on Treatment Dummies

Omitted Category: autkary; Mean expected profits: 51.2

$$\text{ProjProfit}_i = \alpha + \sum_j \beta_j T_j + \varepsilon_i$$

	Limited Information (1)	Full Information (2)	Difference Lim - Full (3)
A. COEFFICIENT ESTIMATES			
Individual liability	-0.83	0.30	-1.13
	(0.94)	(1.18)	(1.22)
Joint liability	1.05	-1.13	2.17***
	(0.83)	(1.17)	(0.76)
Joint liability w/ approval	-3.27***	-1.02	-2.25*
	(1.03)	(1.55)	(1.39)
Equity	1.66	1.29	0.36
	(2.86)	(1.28)	(1.81)
B. TREATMENT EFFECTS RELATIVE TO JOINT LIABILITY			
Individual	-1.88***	1.43	
	(0.69)	(1.40)	
Joint liability w/ approval	-4.32***	0.11	
	(0.73)	(1.40)	
Equity	0.61	2.42***	
	(2.58)	(0.85)	
C. TREATMENT EFFECTS RELATIVE TO JOINT LIABILITY w/ APPROVAL			
Individual	2.44***	1.32	
	(0.46)	(1.93)	
Equity	4.93**	2.31	
	(2.40)	(1.52)	

Notes:

(1) Standard errors clustered at the session level in parentheses.

(2) In full information treatment, all actions and payments are observable. In limited information treatment, all partner's actions are unobservable. Players are informed only if partner earned enough to repay her debt of Rs. 40.

(3) * Denotes significance at the 10%-level, ** at the 5%-level, and *** at the 1% level.

Table 12: Contract Effect on Risk Taking by Risk Type

Risk Taking measured by expected profits

	Information[3]			
	Limited		Full	
	Risk Type[2]		Risk Type[2]	
	Low	High	Low	High
	(1)	(2)	(3)	(4)
Baseline				
Autarky	50.18	52.69	50.18	52.69
	(0.94)	(1.41)	(0.94)	(1.41)
Contract Effects Relative to Autarky Baseline				
Individual liability	0.07	-1.37	-0.04	0.47
	(0.99)	(1.68)	(1.41)	(2.28)
Joint liability	-0.54	12.10***	-0.81	-2.84*
	(0.91)	(4.07)	(1.09)	(1.60)
Joint liability with partner approval	-2.58**	-2.84*	-0.80	-0.41
	(1.29)	(1.57)	(0.94)	(5.03)
Equity	2.91*	0.15	1.32	4.81***
	(1.64)	(3.37)	(2.26)	(1.56)

Notes:

(1) Standard errors clustered at the session level in parentheses.

(2) Risk type based on investment choices in benchmarking rounds.

(3) In full information treatment, all actions and payments are observable. In limited information treatment, all partner's actions are unobservable. Players are informed only if partner earned enough to repay her debt, Rs. 40.

A Sample Instructions

The following instructions are for the joint liability game with limited information. Detailed instructions for other treatments are available on request.

INSTRUCTIONS

Good afternoon everyone and thank you for agreeing to participate in our study. We are conducting a study of how microfinance clients make investments and share risk. Instead of asking you a lot of questions, what we'd like to do is have you play some games with us. The games are simple. You don't need any special skills. They're probably like games you played before. You don't need to know how to read. There are no "right" or "wrong" answers. We just want to understand how you make choices and what sorts of investment you prefer.

Here is how the game works. You will play games where the amount of money you win is based on picking a colored stone. *Display large 100/10 payoff sheet.* One of us will hold a stone in each hand. One stone is white. The other is black. *Show stones.* We will mix the stones up and you will pick a hand. No one will know which stone is in which hand, so the color you get is based on chance.

If you pick the white stone you will win the amount shown in white. If you pick the black stone you will win the amount shown in black.

Play practice round and administer oral test to confirm understanding. Distribute project choice sheets and tokens (carom coins).

We will give you choices about which game you want to play. Look at the sheet in front of you. It describes eight games. The color on the page tells you how much you win for each color stone. If you play game "B" how much do you win if you pick the white stone? How much for the black?

You can pick which game you want to play by placing a carom coin on your choice. For example, if you wanted to play the first game you would put your black carom coin over the "A". *Demonstrate.* And if you wanted to play [the fifth game], you put your coin over the "E".

The choice is yours. There are no right or wrong answers. It's only about which choice you prefer.

You can discuss your choices with the other person at your table, but do not speak with anyone else. Also, while you may talk with the person at your table, you may not look at her choices or score sheet. The first time you look at your partner's sheet, we will deduct Rs. 20 from your score. If you peek a second time, we will have to ask you to leave the study.

We will play several rounds today. At the end of the day we will put the number for each round you play in this blue bucket. Suppose you play three rounds. We will put the numbers 1, 2, and 3 in the bucket and you will pick a number from the bucket without looking. We will pay you in rupees for every point you scored in just that round. Remember, you will only be paid in rupees for one of the rounds that you play today. *Demonstrate example.* Remember, every round counts but you will only be paid in rupees for one of the rounds.

At the end of the day, you will be paid individually and privately. No one will see exactly how much you earn.

Administer second test of understanding.

In this game you will play with a partner. You will use a white carom coin to mark your choices. When you make your choice, we will take your white coin. After you play the stone matching game, we will pay you in chips. The white chips are worth Rs. 5 and the red chips are worth Rs. 20. At the end of each round, you must repay your loan of Rs. 40. You and your partner are responsible for each other's loans. So to get your white coin back, you both must repay your loan. You may not look at your partner's score sheet or see how much she wins. However, after we play the stone matching game, we will tell you whether your partner made enough to pay her loan back.

After you play the stone matching game and receiving your chips, you can choose to give some of your earnings to your partner. You can discuss these transfers with your partner. You do not have to make any transfers. However, you are responsible for both your loan and your partner's loan and will be able to continue playing the game only if both of you can repay your loan of Rs.40.

If you wish to make any transfers, put any chips you wish to transfer to you partner in the bowl in front of you. Do not hand chips directly to her or place them in her bowl. Only place the chips you wish to transfer in the bowl in front of you. This is important because we need to keep track in order to pay you the correct amount at the end of the day. We will then collect your loan repayment.

Your earnings for the round will be equal to the total amount of chips that you have after any transfers you make to your partner and after you repay your loan. If either you or your partner are unable to repay your loan, you will both earn zero for the round and will not receive your white coin.

At the end of each round, we will pick a ball from this cage. There are 20 balls in the cage: 15 are white and 5 are red. If the ball is white, you will play another round of the same game with the same partner. If you do not have your white coin, you will have to sit out and will score zero for the round. If the ball is red, this game will stop and we will play a new game. Everyone will start with a new white coin and be matched with a new partner. After the red ball is pulled from the cage, you will not play with the same partner again for the remainder of the day. At any time, you can expect the game to last four more rounds but we will play until a red ball appears.

If you have any questions at any time, please raise your hand and one of us will come and assist you.

Administer final test of understanding.

Play practice round.

B Proofs and Derivations

B.1 Experimental Design and Discounting

We are interested in the individual utility maximization of the form

$$\max_{c_t^i} \mathbb{E} \sum_{t=0}^{\infty} \beta^t u(c_t^i),$$

where $c_t^i = y_t^i - (\tau_t^i - \tau_t^{-i}) - P_t^i$ as described in Section 3. Because utility is additively separable and there is no scope for savings, this is solved by maximizing the expected utility in each round. As described in Charness and Genicot (2007), if every round counted towards an individual's payoff, she would seek to maximize the utility of the *sum* of income across *all* rounds,

$$\max_{c_t^i} \mathbb{E}u(\sum_{t=0}^{\infty} u(c_t^i)),$$

and could thereby partially self-insure income risk across rounds. When paid for only one round selected at random, an individual's expected utility is

$$\mathbb{E}u(c_{t*}^i),$$

where t^* is the round selected for payment. Thus, optimizing individuals seek to maximize expected utility in *each* round, as desired.

B.2 Autarkic Investment Choice

In autarky, an individual's single-period investment choice problem solves

$$\max_{\alpha} U(\alpha, D) = \pi u[y_h(\alpha, D) - D] + (1-\pi)u[\max\{y_l(\alpha) - D, 0\}]. \tag{4}$$

Because of the discontinuity created by limited liability, this problem does not have a "nice" closed form solution for a^*, the optimal allocation to the risky investment. Under the assumption of constant relative risk aversion utility function, $u(c) = c^{(1-\rho)}/(1-\rho)$, the first order condition for an interior maximum is:

$$\alpha^*_{INT} = \frac{(z-1)[S(1+D) - D]}{[(z-1)S + R](1+D)}, \tag{5}$$

where

$$z = \left[\frac{\pi(R-S)}{(1-\pi)S}\right]^{1/\rho}.$$

Accounting for the discontinuity created by limited liability, the optimal allocation is

$$\alpha^* = \begin{cases} \alpha^*_{INT}, \text{ if } EU(\alpha^*_{INT}) > EU(1) \\ 1, \text{otherwise} \end{cases}.$$ [22]

In the dynamic problem, individuals solve

$$\max_{\alpha} V(\alpha, D_t) = E\{U(\alpha) + \beta V(\alpha, D_t)\},$$

which is equivalent to the solution of

$$\max_{\alpha} \frac{U(a, D_t)}{1 - \beta \Pr[Default|\, \alpha]}.$$

B.3 Informal Insurance and Allocation to the Risky Asset

Definition 1 (relative marginal utility) *For any state of nature $\theta \in \Theta = \{hh, hl, lh, ll\}$ and transfer arrangement $T = \{\tau_\theta\}_S$, let $\lambda_\theta = u'(y^A_\theta - \tau_\theta)/u'(y^B_\theta + \tau_\theta)$. Further, define the autarkic ratio of utilities, $\lambda^0_\theta = u'(y^A_\theta)/u'(y^B_\theta)$.*

Note that the first-best insurance arrangement involves full income pooling, $\lambda_\theta = \lambda^0 \; \forall\theta$, and for individuals with identical utility, $\lambda^0 = 1$. Under autarky ($T = 0$), the first-order conditions for optimal investment allocation require $\pi(R - S)u'(y^i_h) = (1 - \pi)Su'(y^i_l)$, which implies that $\lambda^0_{hh} = \lambda^0_{ll} \equiv \lambda^0$.

Lemma 1 (properties of λ) *For any constrained Pareto optimal transfer arrangement, $T = (\tau_{hh}, \tau_{hl}, \tau_{lh}, \tau_{ll})$:*

1. *$\lambda_{hl} \le \lambda_{lh}$;*
2. *If $\lambda_{hl} = \lambda^0$, then $\lambda_{hh} = \lambda^0$. Similarly, if $\lambda_{lh} = \lambda^0$, then $\lambda_{ll} = \lambda^0$;*
3. *If there exist θ and θ' such that $\lambda_\theta > \lambda_{\theta'}$ then $\lambda_{hl} < \lambda_{lh}$.*

Note that this implies that an individual is relatively better off when her project succeeds and her partner's fails than when her project fails and her partner's succeeds.

Proof. For the first part of the lemma, suppose $\lambda_{hl} > \lambda_{lh}$. This implies that $\frac{u'(y^A_{hl} - \tau_{hl})}{u'(y^B_{hl} + \tau_{hl})} > \frac{u'(y^A_{lh} - \tau_{lh})}{u'(y^B_{lh} + \tau_{lh})}$. But since $y^i_{hl} > y^i_{lh}$, there exists a $\hat{\tau} \in (\tau_{lh}, \tau_{hl})$ such that $T' = (\tau_{hh}, \hat{\tau}, -\hat{\tau}, \tau_{ll})$ satisfies the incentive compatibility constraints for both agents and $\frac{u'(y^A_{hl} - \hat{\tau})}{u'(y^B_{hl} + \hat{\tau})} = \frac{u'(y^A_{lh} + \hat{\tau})}{u'(y^B_{lh} - \hat{\tau})}$. This transfer arrangement increases expected utility for both agents, a violation of Pareto

[22] In this formulation of the model with limited liability, it is never optimal for an individual to choose $\alpha \in \left(\frac{S(1+D)-D}{S(1+D)}, 1\right)$.

optimality. For the second part, suppose $\lambda_{hl} = 1 > \lambda_{hh}$. This implies that A's incentive compatibility constraint does not bind in hh. Therefore, there exists $T'' = (\tau_{hh} + d\tau, \tau_{hl} - d\tau \frac{\pi u'(y^B_{hh}+\tau_{hh})}{(1-\pi)u'(y^B_{hl}+\tau_{hl})}, \tau_{lh}, \tau_{ll})$ that satisfies the incentive compatibility constraints and leaves B's expected utility unchanged. But $\lambda_{hl} > \lambda_{hh}$ implies that $V^A(T'') > V^A(T)$, a violation of Pareto optimality. A similar argument shows that $\lambda_{lh} = \lambda^0$ implies $\lambda_{ll} = \lambda^0$. The third part of the lemma follows immediately. ■

Lemma 2 (symmetric optimal investment) *For any constrained Pareto optimal transfer arrangement with equal Pareto weights, $\alpha^{A*} = \alpha^{B*}$, i.e., both individuals allocate the same share of their assets to the risky investment.*

Proof. By contradiction, without loss of generality, assume that $\alpha^A > \alpha^B$. If full insurance transfers are implementable, then the individual maximizations with respect to investment allocation also maximize joint surplus. For any combined allocation to the risky asset, $\bar{\alpha} = \alpha^A + \alpha^B$, we can solve for the individual allocation that maximizes total utility. The first order condition for this problem requires

$$u'\left(\frac{\alpha^A}{2}R + \left(1 - \frac{\bar{\alpha}}{2}\right)S\right) = u'\left(\frac{\alpha^B}{2}R + \left(1 - \frac{\bar{\alpha}}{2}\right)S\right),$$

which is satisfied at $\alpha^A = \alpha^B$.

If full insurance is not implementable, there must exist two states of the world, θ and θ', such that $\lambda_\theta > \lambda_{\theta'}$. From Lemma 1, $\lambda_{hl} < \lambda_{lh}$. If A's allocation, α^A, satisfies the first order conditions for optimality under the transfer arrangement T, then $\lambda_{hl} < \lambda_{lh}$ implies $\partial V^B/\partial \alpha^B > 0$, contradicting optimality. Similarly, if B's allocation, α^B, satisfies the first order conditions for optimality under the transfer arrangement T, then $\lambda_{hl} < \lambda_{lh}$ implies $\partial V^A/\partial \alpha^A < 0$. Thus, individual maximization requires $\alpha^{*A} = \alpha^{*B}$. ■

Proof of Proposition 1 (informal insurance increases risk taking). As shown above, in a symmetric transfer arrangement, both individuals allocate the same share of their assets to the risky investment, $\alpha^A = \alpha^B$, which implies that the constrained optimal transfer arrangement takes the form $T^* = (0, \tau, -\tau, 0)$. Note that for any transfer arrangement, T, the optimal investment allocation, α^*_T requires $\pi^2(R-S)u'(\alpha^*_T(R-S) + S - \tau_{hh}) + \pi(1-\pi)\{(R-S)u'(\alpha^*(R-S) + S - \tau_{hl}) - Su'((1-\alpha^*)S - \tau_{lh})\} - Su'((1-\alpha^*)S - \tau_{ll}) = 0$. Thus $\alpha^*_{T=T^*} > \alpha^*_{T=0}$. ■

Proof of Proposition 2 (risk taking encourages insurance). Consider a transfer arrangement T that does not achieve full insurance. Thus there exists a state θ where one of the agent's incentive compatibility constraints binds. Without loss of generality, assume that agent A's incentive compatibility constraint binds. From Lemma 1, we know that her incentive compatibility constraint must bind in state hl, therefore

$$u(y^A_{hl} - \tau_{hl}) - u(y^A_{hl}) + \frac{V^A(T) - \bar{V}^H}{r} = 0.$$

An increase in α relaxes this constraint. Therefore, using Lemma 1 and similar to the arguments made above, when α^A increases it must be possible for A to increase her transfer to B in state hl in exchange for an increased transfer from B in state lh that maintains B's expected utility while increasing A's. ■

B.4 Mandatory Insurance and Informal Transfers

To generalize the effect of joint liability or mandatory default insurance on informal risk sharing, I consider a slightly modified economic environment. Assume discrete-time, infinite-horizon economy with two agents indexed by $i \in \{A, B\}$ and preferences

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t u(c_t^i)$$

at time $t = 0$, where $\mathbb{E}_0$ is the expectation at time $t = 0$, $\beta \in (0, 1)$ is the discount factor, $c_t^i \geq 0$ denotes the consumption of agent i at time t, and u is a common von Neumann-Morgenstern utility function, which is assumed to be nicely behaved: $u'(c) > 0, u''(c) < 0 \quad \forall c > 0$ and $\lim_{c \to 0} u'(c) = \infty$.

In every period, each individual receives income y^i drawn from the set $\{y_1, ..., y_n\}$ ranked in ascending order $y_1 < ... < y_n$. Let $\pi_{jk} = \Pr\{(y^A, y^B) = (y_j, y_k)\}$ and confine our attention to the set of symmetric distributions such that $\pi_{jk} = \pi_{kj}$ for all j and k. Denote by T a set of transfer rules $\{\tau_{jk}\}$ where the choice variable τ_{jk} is the net transfer from A to B when $(y^A, y^B) = (y_j, y_k)$. I depart from the standard framework by assuming the presence of a mandatory transfer arrangement $\underline{T} = \{\underline{\tau}_{jk}\}$ that defines a minimum transfer in each state. For any realization of income (y_j, y_k) where $y_j > y_k$, $\tau_{jk} \in [\underline{\tau}_{jk}, y_j]$.

Let $\bar{v}(\underline{T})$ denote each individual's per period expected utility in the absence of informal insurance. Thus

$$\bar{v}(\underline{T}) = \sum_{j=1}^{n} \sum_{k=1}^{n} \pi_{jk} u(y_j - \underline{\tau}_{jk}) = \sum_{j=1}^{n} \sum_{k=1}^{n} \pi_{jk} u(y_k + \underline{\tau}_{jk}).$$

Under a set of transfer rules T, A's per period expected utility will be

$$v^A(T) = \sum_{j=1}^{n} \sum_{k=1}^{n} \pi_{jk} u(y_j - \tau_{jk}).$$

B's utility is defined symmetrically. For a transfer arrangement to be implementable it must be incentive compatible in all states of the world. Thus

$$u(y_j - \tau_{jk}) + \frac{v^A(T)}{r} \geq u(y_j - \underline{\tau}_{jk}) + \frac{\bar{v}(\underline{T})}{r} \quad \forall j, k. \tag{6}$$

Rearranging this equation yields the familiar and intuitive result

$$u(y_j - \underline{\tau}_{jk}) - u(y_j - \tau_{jk}) \leq \frac{v^A(T) - \bar{v}(\underline{T})}{r}:$$

the current period gain from defection must be less than the discounted loss from terminating the informal sharing arrangement.

Let $T^* = \{\tau^*_{jk}\}$ represent the set of symmetric, constrained-Pareto-optimal transfer rules and consider those states of nature where the implementability constraint (6) is binding. I now consider the effect on T^* of changes to the mandatory transfer rules, i.e., what is $\partial\tau^*_{jk}/\partial\underline{\tau}_{lm}$. Define

$$\phi = u(y_j - \tau^*_{jk}) - u(y_j - \underline{\tau}_{jk}) + \frac{v^A(T^*)}{r} - \frac{\bar{v}(\underline{T})}{r} = 0. \tag{7}$$

By the implicit function theorem

$$\frac{\partial\tau^*_{jk}}{\partial\underline{\tau}_{lm}} = \frac{-\partial\phi/\partial\underline{\tau}_{lm}}{\partial\phi/\partial\tau^*_{jk}}.$$

First, note that

$$\frac{\partial\phi}{\partial\tau^*_{jk}} = -u'(y_j - \tau^*_{jk}) - \frac{\pi_{jk}u'(y_j - \tau^*_{jk})}{r} < 0.$$

Therefore $sign(\partial\tau^*_{jk}/\partial\underline{\tau}_{lm}) = sign(\partial\phi/\partial\underline{\tau}_{lm})$. Without loss of generality, consider states where $j > k$ and $l > m$. For $j \neq l \cup l \neq m$

$$\frac{\partial\phi}{\partial\underline{\tau}_{lm}} = [\pi_{lm}u'(y_l - \underline{\tau}_{lm}) - \pi_{lm}u'(y_m + \underline{\tau}_{lm})]/r.$$

Since $\pi_{lm} = \pi_{ml}$ this derivative is negative for all mandatory sharing rules up to full insurance. Mandatory coinsurance in one state of nature *reduces* informal insurance in other states. Intuitively, mandatory insurance reduces the cost of reversion to autarky and thus makes it harder to sustain cooperation.

When mandatory insurance is applicable for the state realized (i.e., $j = l \cap k = m$) this discouragement effect is offset by the fact that mandatory insurance reduces the current period gain for deviation from the informal sharing arrangement. The defecting agent cannot escape the mandatory insurance requirement, which serves to relax the implementability constraint (6). Evaluating the net effect by differentiating ϕ in (7) with respect to $\underline{\tau}_{jk}$ yields

$$\frac{\partial\phi}{\partial\underline{\tau}_{jk}} = u'(y_j - \underline{\tau}_{jk}) + [\pi_{jk}u'(y_j - \underline{\tau}_{jk}) - \pi_{kj}u'(y_k + \underline{\tau}_{jk})]/r,$$

which is positive if and only if

$$\frac{u'(y_k + \underline{\tau}_{jk})}{u'(y_j - \underline{\tau}_{jk})} < \frac{r + \pi_{jk}}{\pi_{jk}}.$$

For CRRA utility, this implies that mandatory transfers will increase informal insurance if and only if

$$\frac{y_j - \underline{\tau}_{jk}}{y_k + \underline{\tau}_{jk}} < \left(\frac{r + \pi_{jk}}{\pi_{jk}}\right)^{\frac{1}{\rho}}. \tag{8}$$

When the ratio of the higher income to the lower income is relatively small or when individuals are relatively risk tolerant, mandatory transfers increase informal insurance.

Appendix

Figure A1: Presentation of Core Game Lotteries